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ALFRED PAYSON GAGE.

BY RUFUS P. WILLIAMS.

The death of Dr. A. P. Gage has removed one of the best known teachers of science in the secondary schools of the United States. For a generation he has been the exponent of physics teaching . For twenty years his text books have been among the most prominent in the country. Thousands of young men have partaken of his tuition and hundreds have gained the inspiration which led to further achievement in scientific pursuits. Through his books he has become known in practically all the high schools, academies and colleges of the land, his texts having had probably a larger circulation than any other series of physics ever published in America.

Alfred Payson Gage was born in Hopkinton, N. H., April 15th, 1836, and died in Boston, February 23rd, 1903. He was the son of Sewall and Eliza (Morgan) Gage, his young life being spent on the farm. At the early age of sixteen he began teaching, his first charge being a district school in Concord, N. H. Believing that he had found his life work, he prepared for college at Colby Academy, from which in 1855 he entered Dartmouth College and was graduated with honors in 1859. He was a member of the Greek Society, "Alpha Delta Phi." After graduation Mr. Gage resumed teaching, going for that purpose first to Westbrook, N. C., and then to Laurenburg, N. C. At the latter place he established a large academy. This institution was so popular that students

were attracted thither for hundreds of miles; in fact it was continued during a greater part of the Civil War, or until 1864.

His profession exempted him from service in the Confederate Army, and a special decree of Governor Vance protected him from state conscription. As money was scarce in the Southern states, his students often paid him tuition in cotton, grain and other farm products. Deciding to go North in 1864, as he had a brother in the Federal forces and was himself likely to be drafted and forced into the Confederate Army, Mr. Gage sold his school property for a small amount of gold, which was then at an enormous premium over Confederate script.

The escape of Mr. Gage from North Carolina was a most thrilling one and was not accomplished without dangerous risks and hair raising adventures. He finally succeeded in reaching an uninhabited island off the coast where he was picked up by a blockading vessel and conducted to Admiral Dahlgren's flagship. The Admiral, once convinced of his identity, readily granted Mr. Gage the necessary passports. After brief service as clerk in the quartermaster's department of Sherman's Army, Mr. Gage started north, but through loss of passports was made a prisoner, as a Southern spy, taken to New York, and barely escaped long confinement as a rebel through the kindly mediations of Governor Gilmore.

In 1865 he was elected master of the Bunker Hill Grammar School, Charlestown, Mass. Five years later he was appointed master in the English department of the Charlestown High School. It was at the time of the annexation of Charlestown, in 1874, that he was transferred to the English High School, Boston, being assigned to teach physics and drawing. His scientific bent had here a large field.

Believing that physics should not be taught by lectures and text books alone, he determined to try a new method. In 1880, Mr. Gage with the coöperation of Superintendent Seaver, inaugurated the first physical laboratory in this country, if not in the world, for the individual high schools. The influence of the laboratory idea is seen by comparing the teaching as it is today, when every high school has its well equipped work shop, with schools of twenty-five years ago when there were none. As no

laboratories existed, there were no truly experimental textbooks or laboratory manuals. Gage's "Elements of Physics," first issued in 1882, was the outcome of the method. Experiments which he had found helpful were minutely described. But there was no sufficient apparatus. Necessity in his case was the mother of invention. Not only did he invent apparatus, but experimental physics was such a popular idea that he must needs manufacture and distribute to such schools as adopted this method of teaching. Being practically forced into the apparatus business, he and his son Sewall issued their first catalogue in 1883 and successfully continued business for many years. The apparatus was designed to be of the simplest sort for illustrating the principles involved, so that every high school could afford to have it. "Gage's $100 set of apparatus" was widely known. Among his inventions may be specially mentioned the porte lumiere for utilizing the sun's rays in place of artificial light for projecting lantern slides, etc., his apparatus to illustrate the second law of motion, also his "seven-in-one" and "eight-in-one" apparatus. He improved and simplified the Atwood's machine, the device for illustrating reflection, composition of forces and velocities, the galvanometer, rheostat, Wheatstone's bridge, etc.

Mr. Gage's published works are *Elements of Physics,* 1882; *Physical Technics,* 1883; *One Thousand Exercises in Physics,* 1885; *Introduction to Physical Science,* 1888; *Physical Laboratory Manual,* 1891; *Principles of Physics,* 1895; *Physical Experiments,* 1897. Since the first book appeared, twenty-one years ago, almost half a million copies of his various works have issued from the press. They have been adopted and used, not only in high schools, but in universities and colleges such as Yale, Cornell, University of Pennsylvania, Wellesley, and many other colleges, as well as schools in England, Canada, Japan and China.

Dartmouth College conferred on him, in 1862, the degree of A. M., and Ph. D. in 1885. Dr. Gage has served on the examining board of Dartmouth and was one of the sub-committee of ten, on Physics, Astronomy and Chemistry, appointed under the auspices of the Natural Educational Association in 1892. Dr. W. T. Harris, Commissioner of Education, in submitting to the Secretary of the Interior the reports of the various Conferences and of the

Committee says, "I consider this the most important educational document ever published in this country."

Dr. Gage's mind was not only scientific, but very practical. In everything there must be utility. He simplified and popularized physics by the closest study. To these facts may be chiefly attributed his success. He was especially interested in electricity, and during the seventies gave many popular lectures in various cities on that subject and on the evolution of the railroad. In style he combined choice and accurate English with vividness of illustration.

He gave himself little leisure for rest or for the cultivation of close friendship. Those who knew him best esteemed him most. Work was to him the great resource of life and in it he found the enjoyment which comes to every successful man. His foresight in business and financial matters was no less marked than in his profession.

"Mr. Gage's interest in the local government of the community in which he lived was deep and intelligent. He was often called upon for advice as to the best policy to pursue, and to serve upon committees to formulate such policies. He also thought deeply upon the greater interests committed to the care of State and Nation, and had formulated his own conclusions, to which he was ready to give voice on occasion."

He was a firm believer in Democratic principles as exemplified by ex-President Cleveland.

September 20th, 1859, he married Mary Elizabeth Prescott, of Deerfield, N. H., who assisted him in founding the Academy at Laurenburg, N. C. Of a family of five sons and three daughters there survive all but one son. Of a modest, retiring disposition, Mr. Gage was singularly adverse to anything that savored of pomp or show, preferring to live a simple life. Death came as a result of a complication of diseases, only five months after his resignation, by reason of ill health, from the position he had held for twenty-seven years in the English High School of Boston.

THE SCIENTIFIC METHOD IN HIGH SCHOOL AND COLLEGE.*

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In searching for a topic of general interest to the science teachers here assembled, I could think of nothing more appropriate or important than the general method of all the sciences and the various modifications of that method characteristic of each science as related to the work of the science teacher in college and high school, and I have chosen this topic because it has often seemed to me that the facts of the sciences, the multitude of objects with which they have to do, the varied apparatus which most of them bring into use, and the interesting mechanical processes involved in elementary science work, have often exercised a kind of fascination over the science teacher, engrossing his interest too largely, to the partial neglect of the mental methods to which these facts and processes owe all their truly scientific character.

A science is a body of knowledge, classified, generalized, and rationalized or explained; and the processes of classification, generalization, and causal explanation, together constitute what we call the scientific method. These are all processes of which we make almost constant use in nearly all our thinking and in most of our intelligent active life. We begin to discriminate, to classify, to generalize, and to infer—of course in a very simple way—long before we have learned to read, and we never outgrow the necessity for the constant use of these intellectual processes until we cease thinking and acting altogether. Upon the thoroughness of our command and the correctness of our use of them depends much of our happiness and most of our success, and a course of school training which does not take them into practical account is evidently deficient in an important element of that preparation for life which is the end of training and the object of the school.

Huxley taught that science is nothing but trained and organized common sense, and the question, therefore, whether the scientific method should be deliberately used in science teaching is a

*An address delivered before the Central Association of Science and Mathematics Teachers at Chicago, April 10, 1908.

question whether common sense should be deliberately organized and trained, or whether the ordinary man may be safely left to train and organize his common sense himself. Now I think that it is unquestionable that if the scientist needs to be trained in the scientific method, as so defined, for the fit performance of his labors as a scientific man, then the ordinary citizen needs it very much more for the fittest living of his ordinary life. The art of right and rational living is the most difficult of all the arts, and the most complicated and perplexing of all the sciences are those which underly that art. The task of the investigating chemist in his laboratory, or of the botanist in the field, is simple indeed as compared with the bewildering difficulties which beset the father of a family, the citizen of a community, the voter in a democracy, the physician in charge of the health and lives of hundreds of his fellow men, the business man, whose transactions reach to the ends of the earth, and are inextricably entangled in every direction with the affairs of thousands of others, over whom he has little or no control.

We solve the great problems of practical life by the reference of particular cases, as they arise, to established and accepted general principles; by reference of them to ready-made generalizations drawn from our own experience; or by new judgments based on our general knowledge and on our previous acquaintance with similar instances; and hence we need for their solution not only a store of applicable general principles and much practice in their application, but the power and the habit also of generalizing our own experience accurately and holding the results tenaciously, and the habit of revising general notions freely in the light of new occasions. We need, that is to say, a thorough comprehension and a practical command of that method of assembling, organizing, and rationalizing facts of all orders which in scientific matters we call the scientific method. An example or two from practical life will illustrate.

In an ordinary minor medical experience there is involved a determination process; the assignment, that is, of a case of illness to its proper place in the classification of diseases, or the recognition of a pathological state by means of the visible and tangible characters which it presents, and the use of such remedial measures as

have been associated in the physician's knowledge with this disease or condition. In more difficult or unusual cases, there is a more definite reasoning from effect to cause, as the physician studies the various indications of physical disturbance presented by the patient and infers from them the precise nature of the existing disorder; and reasoning from cause to effect, as when the history of a case is analyzed and a selection is made from the various items of this history of those which there is reason to believe are causally connected with the disordered condition. A double hypothesis is thus framed, and upon it a program of treatment is based, involving the application of remedies and the removal of such causes as remain. This treatment is in the nature of a verification process covering the whole series of observations, and the course of reasoning following thereupon.

I well remember the discussion, in my presence, of a case in which I was deeply interested, by a friend and eminent physician of this city who was good enough to do his thinking aloud as he debated with himself concerning the cause of a group of rather puzzling symptoms in the case before him, and it would be difficult to devise a neater illustration of the practical use of the logical method of residues. Reviewing the list of conceivable causes of the observed effects, but eliminating them one by one because if existent they would have been attended by other symptoms not present in this case, he finally had but one possible cause remaining, and upon this conclusion he based his treatment for its removal. He framed a hypothesis, that is, which was finally verified completely by the outcome of his treatment. The whole scientific process was here excellently exemplified, and it was a pleasure to watch the sure and simple workings of that well-trained mind; and yet just where in all his ordinary educational experience, preliminary or professional, may the prospective physician now look with confidence for just this training which he so clearly and deeply needs? It is the gist of my present argument that his education in the elements of the scientific method should be had in advance, at the expense of clams and earthworms, or, better perhaps, of beans and corn-plants, and not in professional practice at the expense of the health and lives of men.

And so a business man laying in his season's goods and affix-

ing prices thereto, or the farmer in planting his crops for the year and deciding on the special treatment of his land, or in determining the kinds and amounts of his purchases of stock and the special ends to which they shall be fed, so far as he does not merely follow an average routine and take his chances on the outcome, must collect and compare and classify and generalize his facts, and reason to practical conclusions under the guidance of knowledge and experience previously acquired, and test these conclusions by the success or failure, greater or less, of his undertakings, and the profit or loss on his investments—all of which is obviously the scientific process, just as much as if these men were physicists or biologists engaged in original research.

And even in law, which has been for centuries the citadel of educational conservatisms, we begin to hear that science is becoming indispensable. Especially in preparation for that rapidly growing branch of legal practice which aims at constructive rather than destructive work, we are told that the more science there is put into the curriculum the better, for lawyers of this class are aids and advisers in the organization and management of large business affairs, and since there is no branch of modern business which does not require scientific knowledge, the more science of the most widely different kinds the business lawyer has the better for his business usefulness. Sooner or later it all comes into play.

But it is not in these common practical pursuits that a usual reliance on the method of science is most essential, for if one errs in such matters his error presently betrays itself, and he corrects and refines his method next time as a result of his unfortunate experience. It is in those matters of belief and practice whose results cannot become apparent to the man at the time, but only, perhaps, to his children or to his successors after he is gone; it is in those political and social theories which only the experience of generations and the ultimate welfare of nations can fully verify; it is in those subjects so complicated and those series of happenings so variable that human intelligence cannot trace connections of cause and effect with convincing certainty, that an unwavering adherence to a sure and sound method is absolutely indispensable. And most of all we need it where, unchecked by the outcome of experience, we are powerfully swayed by emotional motives, and

are hence most likely to go far astray with seemingly complete impunity.

In short, in all one's personal activities, in his business and professional occupations, in his more or less speculative reflections, in the general ordering of his mental life, in all that pertains to him, indeed, which contains a rational element, the scientific method has its value and its use, for it is simply the method of right reasoning applied to matters of fact.

And next we have to see whether, and how, and in what forms, and to what extent, we are now giving in our science courses this particular kind of practical training so much to be desired.

But, first, I ought, I think, at this point to recall the fact that the method of science is not limited by any means to the sciences themselves as commonly so called, that is, to mathematics, chemistry, physics, biology, and the like. The parts of speech are classes, and the rules of grammar are generalizations, as strictly so as are the laws of nature; and the facts of history may sometimes be causally explained, and the explanations given may be verified by deduction, although not by experiment. But it will be unnecessary, I am sure, to argue here that the sciences of nature have a value, especially in the matter of causal interpretation, which is unique and irreplaceable as a means to an end we have in view.

"The great peculiarity of scientific training," says Huxley in his after-dinner speech on scientific education, "that in virtue of which it cannot be replaced by any other discipline whatsoever, is this bringing of the mind directly into contact with fact, and practising the intellect in the completest form of induction; that is to say, in drawing conclusions from particular facts made known by immediate observation of nature. The other studies which enter into ordinary education do not discipline the mind in this way."

Among the scientific subjects themselves, mathematics is, of course, eminently a deductive science, and is universally and almost necessarily taught from beginning to end as an exercise in deductive reasoning. Chemistry and physics, on the other hand, are primarily inductive sciences except as certain parts of the latter are deductively derived from mathematical conclusions. But, neverthe-

less, as I examine what I am told are the usual operations of the chemical and physical laboratories of instruction and the usual methods of presenting and developing chemical and physical principles, these subjects seem to me to be taught almost wholly by deductive methods. In elementary chemistry, as I have seen it taught, I find three classes of ordinary operations, and, first, the determination of the properties of known substances—lead or hydrogen, for example, by the application to them of prescribed tests. That is, the student observes, under direction and by the aid of simple apparatus, and notes the results of his observation, perhaps comparing also lead with copper and hydrogen with oxygen, or the like. As the next step he examines unknown substances and mixtures of such substances, again by the application of prescribed tests or the use of described processes, notes the results of such applications, and compares these results with those set forth in descriptive tables, and thus he determines his chemical substances by a different mechanical means, but by identical mental processes with those used in determining the name and place in classification of an animal or plant—observation and comparison again, with perhaps the rudiments of classification, but, as yet, no inference. And, further, experiments are made—again under direction—to illustrate chemical laws, either given in advance, as is commonly the case, or brought forward after the experiment by way of an explanation of the results arrived at. Here we reach deductive inference from general laws to single instances belonging under them, but of a true inductive procedure I find little or no trace. If the student constructs a formula expressive of a compound reaction, again he reasons deductively from what he already knows by previous observation and instruction to what he now wishes to find out. He recalls a generalization previously made as to the behavior of certain substances when brought together under the conditions of chemical interaction, and merely recognizes the case in hand as a particular instance of the same class.

This is all extremely valuable, beyond a doubt, as practice in exact observation, in careful manipulation, in accurate comparison, in sound deductive inference, but its scientific method is incomplete, comprising neither inductive inference nor the con-

struction of hypotheses, nor the experimental verification of them; and, furthermore, its very exactness, the unvarying and indubitable certainty of its results at every step, while invaluable in one way, is a defect from another point of view; for we must learn somewhere to deal intelligently and safely—that is to say scientifically—with the merely probable, must learn what to do with variable and uncertain data, to frame more or less doubtful hypotheses, and to devise merely approximate tests of their validity when no better can be had. For our method of science, if it is to be applicable as a guide to life, must correspond as closely as may be to the method of life; and the method of life, if I may use such a term, is very far from exact; many of its most important problems—so essential to action that some solution of them must be reached—often cannot be exactly solved. Our education falls sensibly short of what it should be for us if it does not help us to answer in the best form possible a multitude of questions forced upon us, but which no one can answer in advance by a clear-cut yes or no.

In the common courses and methods of practical work in elementary biology, I find that much more attention seems to have been paid to observation than to reflection, and to mechanical detail than to any characteristic or highly important training of the mind. I do not say that this is not best or at least inevitable, but I think that it is well worth while to make the inquiry. In the ordinary work of a biological laboratory on a series of selected types the student observes, draws, and sometimes describes, the forms and structures placed before him, using a simple set of instruments gradually to prepare the object for his observation. Later he compares each of his types with those studied before, and thus he may be led to generalize the results of his observations in a simple way. He is taught a few of the laws of comparative anatomy, and learns to recognize cases of homology, instances of specialization, differentiation, and the like; that is, he either reasons deductively, following the path which the teacher has opened and cleared before his feet, or else, by a classification process, he refers the items of his newly acquired knowledge to their places in the general system of ideas of which he has become possessed. He may thus come to recognize cases of

assumed causation, the agreement of his observations with certain doctrines concerning the causes of biological phenomena of which he has had perhaps an outline given him, but which he is, of course, in no position either to criticise or to verify. The great mass of his work, however, is that of mechanical manipulation and elementary observation pure and simple. The little reasoning he is led to do is in the nature of deductive inference, and there is practically nothing of an inductive search for causes, nothing, consequently, of hypothetical judgments, or of the verification of such judgments by additional observation and experiment. Furthermore, if questions are put to the student as to the meaning of structures, as to their use in the animal or plant economy, he is, in the absence of time or opportunity for pertinent observation of the living animal or for precise experiment with the plant, usually left to what is perhaps the most treacherous of all the logical methods, that of reasoning by analogy; and finding no means at hand for testing his conclusions and being provided with none, he is much too likely to acquire undue confidence in an imperfect and misleading method. Indeed, as I examine the questions or so-called problems proposed in many of the laboratory manuals of elementary biology I find that very many of them—most of them, I think—either call for observation merely, on matters to which the question simply serves to point the attention, or make demands on the student's knowledge of facts and powers of analysis which it is wholly unreasonable to expect him to meet.

So far I have been engaged in the comparatively easy work of criticism; making difficulties and not removing them; stating problems which I have not tried to solve; and your patience in listening to this part of my discussion is perhaps due to a not unreasonable hope that I will presently change to a more inspiring strain. If our past has been faulty, and if our present aims and methods are defective, are these defects remediable, and, if so, how?

It will perhaps seem to you that I flinch from the kicking of my own gun when I say that I do not think that I ought to be expected to answer these questions, at least not at all definitely and finally. But, really, if I were to try to do so it seems to me that I

should be assuming for myself in the beginning the functions which this new society is actually organizing finally to perform. No doubt, however, I shall be expected to make at least some suggestions towards a solution of our problems, and this, however reluctant, I must try to do.

First, what may we do to improve our college work in this respect? If I may speak from my very limited knowledge of what is now actually done in the science courses of the colleges represented here, I should say that we might perhaps improve our work materially by correlating our different science departments with each other and with the department of logic, with respect to a knowledge and use of the scientific method. A great part of every serious scientific research is nothing more or less than applied logic. Indeed, one might almost say that it is only in scientific studies that logic has any important application in a college course, and yet it is still taught more generally, I think, from the philosophic standpoint than from the scientific, and is taken more commonly by literary than by scientific students. If taught without reference to the sciences, logic is left in the air, an academic study merely, pursued by itself and to its own ends, and with no very definite utilitarian outcome; while if taught with reference to the sciences it becomes one of the most useful subjects of a college course. Logic should be taught, then, at a time and in a way to make it a fundamental part of any science course, and any student specializing in science should be expected to study this logic, so taught, so thoroughly as to master it as a practical instrumentality in his scientific work.

Then, in each separate science—chemistry, physiography, biology, and the like—the distinctive features of its characteristic method should at some time be brought clearly into view and compared with the characteristic methods of all the other sciences, so that the student, whatever his specialty, may learn to reason broadly and intelligently on topics of any class; and this should be done, I think, conscientiously, thoroughly, and as a matter of the highest interest, at the sacrifice, if necessary, of some details of fact and some niceties of instrumental manipulation. Any one would rather that his boy should know how to think clearly and correctly, and how to tell when a thing is proven to a certainty, and what, if not

so proven is the probability of the conclusion reached, than that he should have a little more knowledge of the facts of physics or geology at his immediate command. Indeed, I would make the general principles and the characteristic features of the *method* of physics or chemistry or biology as clear to the student and as definite as the *principles* of these sciences, and would develop in the course of my instruction the *general method* of science with as much care and fullness as I would any *scientific principle or law.*

Especially I would see to it that suitable opportunity is found or made for thorough training of a practical sort in the various kinds and forms of the *inductive search* for truth. We have already seen that the deductive process predominates in nearly all our work. It is the characteristic process of the studies of a literary course, and tends constantly to insinuate itself into nearly all our science teaching; but to this tendency we must certainly offer strenuous, though discreet, resistance, for without inductive teaching we entirely miss one of the chief values of a science course, and the one thing in it, I think I may say, of the greatest practical use.

And we must distinguish carefully between the induction of the so-called exact sciences, in which the logical method of difference is the main dependence, and that of the sciences sometimes called inexact, in which we are frequently limited to one of the less conclusive methods, and in which, consequently, our results have only a probable value. We must also recognize a highly important difference between inductive operations performed on like and unvarying data—such as those of physics and chemistry, where one specimen of a class or one instance of an action is as good as more, since we know in advance that all are precisely alike—and those performed on variable objects like living animals and plants, where no two are exactly similar, and all are peculiarly sensitive to the modifying influence of an immense number of variable and constantly varying conditions. In cases of this latter sort, in problems of animal ecology, for example, we can reason safely only from masses of particulars of each class, from collections large enough to represent the average of their kind, and our conclusions can be true of average cases only, or of whole groups taken as one.

The necessity for this distinction comes out in a very inter-

esting way in much experiment station work, where discordant results are brought out by different workers because neither has used plants or animals enough in his experiment to eliminate or cancel individual peculiarities, and these have, consequently, appeared in the conclusion reached in a way to cast discredit on the whole experiment. Indeed chemistry and physics are to induction what mathematics is to education, and too narrow a training in either may disqualify for work in another field. As an exclusively mathematical training would not be good for a lawyer, so too exclusive a training in exact physical science is not a good preparation for biology; and if not for biology, then not for life, for we must remember that human life is really a division of the biological field, and that the biological methods are those most applicable to what we call practical affairs.

And now what may we say of the improvement of high school work in respect to this subject of the science method? If I am to be frank with you, I must say at once that I do not know; and yet I should be much less like the average man than I am if I were to let my knowledge of that fact stop my mouth. Indeed, I believe I feel a little freer to say things on this subject than I should if I were speaking with the authority of practical experience or even of much observation, for I know that there are numbers here with such experience able and ready to correct at once any errors into which I may fall.

In the first place, can we teach the use of the scientific method at all in the high school? The term has a formidable sound, and suggests the spectacled adult, and some of you I fear are even now suppressing your smiles as you think of introducing practical logic to the athletic boys and the romantic girls of your high school classes. But however collegiate the name may seem, the thing named is in its simpler forms of kindergarten grade, and we have all noticed, no doubt, the essentially scientific inferences sometimes amusingly shrewd, made by very young children. I happened to know two little ones, four or five years old, each of whom had spontaneously and quite independently thought out a childish theory of the origin of the wind. Seeing the trees always waving whenever the wind blew, and quiet when there was no wind, the conclusion was reached, as if by the method of agree-

ment, that it was the waving of the trees which made the wind—a conclusion verifiable after a fashion by the experiment of one's self waving a little tree and thus making a little wind. Indeed one of these little ones first betrayed his peculiar notion by asking for little trees to set beside his pond to make the wind blow on the sails of his toy boat; and the other—a young woman now—tells me that this childish idea remained so long undisturbed and became so firmly fixed that she still naturally thinks of the wind as coming from the trees. Now I think that it would be safe to say that anything that a child does fairly well spontaneously it can be taught to do much better; that is, at any rate, the kindergarten principle.

Whether such teaching could be made of sufficient interest or not is not for me to say. To some it may seem that the subject smacks too much of dry formalism to have any proper place among the enthusiasms of the young; but we may study form without real formalism, and some such study is helpful, is necessary even, if the best fruits of enthusiastic interest and endeavor are not to be thrown away. Literature without rhetoric, language without composition, history without reasoning and reflection, art without aesthetic principles, may be pleasing to the imagination or inviting to the eye, but they are gelatinous to the touch; there is no progress in their motions because there are no bones in their flesh—and such as these are, so are the sciences without the scientific method. It is worth while to study the structure of a language, for without this it is not a language, but only speech; it is worth while to learn the causal connections of historical events, for without these we have only narrative; and it is worth while to study the method of a science, for without the use of this it is not a science at all, but only facts. That we do not give at least as much attention to the method of science as we do to the structure and use of language is due, I suppose, to the fact that science is modern while language is old. Indeed in the one science which is almost as old as literature—mathematics—we do study its method elaborately, and it is not an accident that no one doubts the value of that subject as a means to an increase of intellectual power, while it is still a question for discussion whether natural science, as taught by many of us, really trains anything but the senses and the fingers.

In high school, as well as in college, the great difficulty attaches to inductive work. I lately asked a group of half a dozen senior college students in biology each to prepare for me a list of zoölogical problems suitable for use in high school work, and of the forty problems handed in all but six called only for deductive inference, and these six—presented by an advanced botanical student—were adaptations from the program of experiments in plant physiology on which he had lately been at work.

As to the methods of procedure and materials for the work I only venture to suggest that the primary requisite is a copious and varied list of problems for individual solution, mainly by inductive reasoning from the student's own observations and experiments. It will be helpful, of course, if this list affords materials for a program of connected studies leading up by natural steps to general principles, but this should not be the main end in view. The especial purpose should be, I think, to illustrate and establish the inductive method with materials of various kinds, beginning, of course, with easy observations and experiments which lead to certain conclusions, dealing later with variable data to be treated by the method of averages, and ending with the estimation or the calculation of degrees of probability. The subjects proposed would thus be such as to familiarize the student with the various logical methods, not by name, but by actual use, and he should come to understand their relative values and the ways in which each may be made to supplement another. For a supply of such problems good text books will be of use, but the literature of investigation must be searched, where an abundance of problems may be found capable of such simplification as to bring them within the reach of the student's capacity and the conditions of the school. I think especially, as I write, of Professor Davenport's two-volume work on experimental morphology, and the copious literature of the agricultural experiment stations of all the states—for I am obliged to take my examples from subjects with which I am myself somewhat acquainted. Such materials will sometimes work into the regular program of an entire class, and this is, of course, very desirable indeed; but even if they will not, they may be made accessory to such work, I should suppose, to very good advantage.

It is not, I think, so very important that all inductive gener-

alizations should be arrived at by induction, but it is the important thing that abundant and varied practice in induction shall be had, to the end that the pupil may thoroughly acquire the art of inductive inference. A law may be stated, illustrated, and verified either by experiment or by a history of the method of its discovery, but it is not necessary either to its comprehension or to confidence in its truth that it should always be developed from the pupil's own experience. But I must not occupy any longer the very valuable time of this meeting with crude attempts at practical suggestion, when there are many here far better prepared than I to help us at this point.

The sum of what I really have felt impelled to say this morning is only this: that our science teaching may be materially strengthened and made practically far more valuable if we will give much more attention and thought than hitherto to the rational action of the mind in science work, especially in the matter of inductive inference; if we will bestow as much care, ingenuity, and skill upon the selection, adaptation, and arrangement of materials for the training of the mind in the processes of logical reflection on the products of experience as we have heretofore used in equipping laboratories, and in teaching our students how to see, to manipulate, and to describe.

SOME OBSERVATIONS ON THE TEACHING OF PHYSICS.*

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It seems not to be generally known among science teachers that the study of science is declining all along the line in the high schools of this country. The high water mark was reached about the year 1885. Since that date there has been a steady falling off in the attention given to every science taught in the schools. Physics has held its own better than most of the others, but even it has been losing ground, and that steadily.

A brief glance at the actual figures which represent these facts will be more impressive than general statements. At the same time, let us note those studies which are receiving the increased attention which this decadence in the study of science has occasioned. The facts will be sufficiently presented if we take the decade between 1890 and 1900. During that decade, geology, astronomy and chemistry have fallen into disfavor until altogether they receive the attention of less than 20 per cent of our high school pupils. Physics has fallen off about 14 per cent during the same ten years. Physiology and physical geography have scarcely held their own. The best conclusion that can be drawn from the facts would seem to indicate that there has been a falling off of 15 to 25 per cent in science studies in the high schools of the United States since 1890.

It might be supposed that literature, English and history would be the studies to receive the attention which these sciences have lost, but not so. This loss to science has gone to swell the ranks of the last two classes in the whole curriculum which one would be likely to name; or at any rate, nearly everything else has been named first by those to whom I have presented the query, These two studies are Latin and algebra.

In 1890 45 per cent of all the high school pupils in the United States were studying algebra; in 1900 the per cent had risen to 56.

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In 1890 34 per cent of these pupils were studying Latin, and in ten years the rate had risen to 50.6 per cent. Thus we see a relative increase of 24 per cent in the attention given to algebra and 16 per cent for Latin. During this time the attention given to the three greatest studies of the curriculum, literature, English and history, has increased but slightly, and has all along been far below that given to Latin and algebra. More than half of our high school students are studying Latin and algebra every day in the year while little more than one-third of them are studying the most potent themes of education and interest to the human race. One stands amazed before this strange spectacle in our educational development.

It is interesting to note in this connection that Latin and algebra receive least attention in the north Atlantic states and the north central states, and most attention in the southern states and the states west of the Mississippi. One is reminded of Booker Washington's statement that the two besetting sins of his race are the desires to hold office and to study Latin. Surely the negro is not so unlike his superior white brother after all, is he?

It would be easy to brush these facts aside with the assumption that this running after Latin and algebra is a mere craze or fad. It might flatter our whims to assert that the American people are fond of fetishes and foibles and so excuse ourselves of any responsibility for these unexpected mutations in the educational program, but it would hardly be in keeping with a true scientific spirit, nor would it contribute to the educational interests of our country nor to our success as teachers. Let us, therefore, look for some of the more fundamental reasons which underlie this movement.

There are some educational features which are peculiar to both algebra and Latin, and which tend to afford them a unique place in the school curriculum. They both belong to the group of memoriter subjects and are reasonably free from any taxing demands upon the higher rational processes. Both are thoroughly organized subjects of study and proceed by definite and easy steps to a definite end. Both are free from library and laboratory work and so relieve both student and teacher from those embarrassments which are incident to that kind of work. Both belong to the

general culture subjects as distinguished from the practical subjects of the curriculum; the very fact that they have little practical value in life tends to give them a kind of distinction all their own, to lift them out of the realm of the sordid into the atmosphere of that which seems to have a halo of culture for culture's sake. Both are foundation studies for college work rather than for practical life. Both are pursued continuously for a long period of time and so produce a strong impression on the mind from the very constancy and continuity of the repetition of elements employed. And, finally, both are easy to teach and easy to learn because of their perfectly definite character, their simple academic content and the easy steps by which they are pursued.

You of all people do not need to be reminded that every cause has its certain effect in the intellectual as well as in the physical world, and that each of these several factors which have just been enumerated has had its influence in producing the conditions which exist in the high school curriculum. It is undoubtedly true that Latin and algebra are studied by many pupils because they want to be in the popular course. Many cite the college and university as important influences in the situation. Indirectly they undoubtedly do exert a powerful influence, but on the whole this influence is much less than is popularly supposed. Less than 12 per cent of those who attend a high school complete the course to graduation, and of these less than one-fourth ever go to college. A few who are not high school graduates attend college, but the whole college and university attendance is only about 3 per cent of those who attend the high schools of the country. From this it would seem to be evident that this large number of pupils in our high schools do not study Latin because they expect to attend college. The indirect influence of the college seems to give the impression among the half educated that it adds dignity and distinction to an individual to study Latin. In some measure algebra is looked upon in the same light, though another important factor in this connection is the fact that the average American believes mathematics to be about the greatest study ever invented, and so aspires to an ever increasing amount of that study which is the high water mark of mathematical profundity in the high school. It has long been conceded that algebra is overdone in our high schools and

at the same time its patronage is increasing yearly. Most of those whom I have consulted express the belief that Latin is likewise a much overdone subject. Now the question is, are the people right in this large and increasig demand for two such subjects as Latin and algebra or are they wrong? I believe a careful investigation of the situation would show that with the conditions that actually exist the people are right in preferring algebra and Latin to a larger amount of science. I believe also that the people are wrong in that they do not make the conditions such that literature, English and history and the nobler sciences may be preferred for a better place in the high school curriculum. Certainly these subjects are much nearer and dearer to the people and far more in keeping with their interests than are so much Latin and algebra.

One of the chief reasons why the three great English culture subjects named are not more studied is that they are so poorly taught. Teachers of English and history and literature are not to be compared in skill with teachers of algebra and Latin as a rule; or, to state the case more accurately, a teacher who could teach Latin with marked success is more than likely to be a questionable success, if not a positive failure, when it comes to teaching the more difficult subjects. The people must learn that it requires a better equipped teacher for science and English than it does for Latin, and that the expenditure for libraries and laboratories should be generous. Also it requires a natural teacher and one possessed of superior ability to teach these difficult subjects well. Latin tutoring is a common and acceptable phrase, but who ever heard of science tutoring? The very expression provokes a smile. And still the average high school patron imagines that any one who has studied a little science and who is equipped with a small room and a text book can teach physics. It would be interesting to discuss more fully the causes of poor teaching in the various subjects named, but as we are here concerned chiefly with physics teaching, let us consider why it is that physics is not better taught and what may be done to restore that important science to its proper place in the high school curriculum.

Physics is an exceedingly difficult subject to teach. From the modern point of view it is a new subject; not even its aims are yet clearly defined. No two teachers can agree on methods.

Every fad and freak idea has its considerable following. Text books are mostly uninteresting compendiums of definitions, technicalities and formulæ. Laboratories, where they exist, are full of useless toys and antiquated devices for demonstrating how things can not be done. The people have not yet been educated up to the necessity of providing adequate facilities for teaching science, and teachers themselves seem, in many cases, to have settled down to a kind of hopeless acceptance of the situation. Fewer sciences are taught now than formerly, and that is well, but a compensating increase in time and attention has not been given to the few taught. The vast field and varied character of the subject matter of physics places the teacher under a constant temptation to rattle around in the subject and to substitute enthusiasm and good will for well defined aims and purposeful methods.

Then, too, it is far more difficult to hold the student to definite, accurate work in physics than in Latin and algebra. For in physics it is not so much the particular fact or the special statement of the fact that is wanted as the reasoning and clear and clear-cut conception of things, and these may vary so much and still be good that the tendency is to accept efforts that do not contribute to the positive growth of the student. The teacher who can hold each pupil responsible for some definite, progressive preparation and thought work in each day's effort is no ordinary person; and when he can do this and at the same time direct these daily efforts with such wisdom as to make them culminate in a high degree of discipline and culture as well as knowledge, he is certainly one in a thousand. As our ideals advance and our common fund of experiences increases we shall develop more and more of this high type of science teachers.

The practical or utilitarian value of physics seems to stand as a positive obstacle in the way of its success. In most high schools, this seems to be the chief, if not the sole aim, in the study. The more cultured portion of the public looks upon this aim as narrow and on the whole not worth what it costs. The heedless and improvident are repelled by its practical and severe character. Practical things are likely to be disagreeable to unpractical minds unless they are brought by judicious leadership to appreciate them. The culture values of physics are supposed to be slight and even by

teachers themselves they are commonly ignored. One of our leading writers on education has said in one of his recent books that science has little or no ethical value as a study. It is difficult to conceive of the dearth of scientific knowledge of an otherwise intelligent man who could subscribe to such a statement as this, but it undoubtedly represents the views of a large portion of the general public.

These utilitarian aims in school studies are and always will remain unpopular, and deservedly so. I do not believe any study can ever justify its place in the high school curriculum on this basis alone. The most difficult as well as the most valuable thing to put into the life of a student is culture, moral and intellectual attitude towards life and environment, spirit and purpose; and every study in the high school should contribute to this end. But there is another thing about this utilitarian aim; it generally fails to secure even the one end for which it is taught unless it is so presented that an absorbing interest gives it an abiding place in the mind of the pupil. We all know that our students seldom remember even for a half year those things we count most dear in physics. Why teach them then? the people ask. Teaching in physics that is good must secure not only knowledge but discipline and culture. When we shall give the student in physics as good or better discipline than that afforded by algebra, and teach him to derive from the data of physics satisfying and inspiring truth, and a broad, intelligent, scopeful knowledge not simply of the mere fact but of the great creative principles themselves so that physics shall have life values as well as work shop values, then the study of physics will not be declining in our high schools.

But let us turn to the brighter side of this matter. Physics as a high school study does most emphatically have other educational values, and those of a high order. I asked a distinguished university president recently whether he considered the ethical values of physics and biology as great as those of Latin. He answered without the slightest hesitation that they should be greater if those subjects were properly taught. There is no other subject in the entire school curriculum whose ethical values seem to me to be so potent in certain directions as those of physics. No other subject is so well adapted to impart and establish an unswerving

impartiality in the weighing of evidence and a love of truth based upon unimpeachable premises. The ethical values of physics may be fairly stated under two propositions: First, its highest culture value lies in its capacity to produce on the mind of youth the absolute conviction that every occurrence in this universe is in accordance with law and order, and that it always has been so and always will be so. No other truth with which I am acquainted has such power to emancipate the mind from the intolerable thralldom of superstition and ignorance which still hangs like a pall over the mass of humanity. It could hardly be possible for any young man with a well balanced mind to study physics and biology for four years under the guidance of live and competent teachers without finding it impossible thereafter to maintain an unquestioning faith in the many stultifying dogmas and hypocritical pretensions that are still dominant in this new twentieth century. Why is it that most of our college graduates are either bald skeptics or at best negative Christians? It is because their faith in the old superstitions and time honored creeds is no longer tenable; and with these once cherished notions destroyed, they are turned out upon the world with nothing but the cold utilities of a scientific age to take their place. Let us fill our pupils with the spirit of truth as well as the facts of truth. Let us teach them to love principle and harmony and justice and to worship the divine in all things that are good and true and to see that the right thing is the only profitable thing because it is the only possible ultimate thing.

The second proposition is this, physics tends to secure to the growing mind of youth the highest type of moral and intellectual integrity in that it substitutes reason based on scientifically established premises for mere logic. One of the greatest accomplishments of this scientific age lies in the fact that the spirit and method of science are making it forever impossible again to reason acceptably on poorly established premises. John Fisk, one of the few really great teachers, in that rare little gem "Through Nature to God" says, "the foundation of morality is to give up pretending to believe that for which there is no evidence." Surely there is no other subject better adapted to laying such foundations than physics.

The text book problem is one that has not yet been solved for

the physics class. A few suggestions along this line may serve at least to stimulate some thought on this important matter. There are at least three types of books which it would seem should be of special interest to the physics teacher. First there is a class which we may call nature books. Most of these books are excellent in their way. They are seldom used as class texts, but it would be well if they oftener found their way onto the reference shelves of the science library. They deal with the interesting facts and phases of physics, or with the broad scopeful theories about physics and its applications. They give a student those large views of things which the aspiring mind always delights in. These books should be ready at hand and should be so familiar to the teacher that ready reference may be made to them at any time. They contribute more to the pupil's interest in physics than any other kind of books. They are free from definitions, mathematics, and all technicalities, and have the merit of leaving a quantity of useful knowledge and a decided thirst for more in the mind of the pupil. As teachers we should give this class of books more attention with a view to making a wider and more intelligent use of them in our classes.

Another class of texts comprises those from the hand of the university teacher. Several of these books have appeared within the past few years. As with the other class they are not much used as actual texts in the classes of the high schools. Some of the distinguishing characteristics of this class are first that they treat fewer topics than the usual text book, and attempt to present those treated in a more thorough manner. Another characteristic is seen in the rather technically scientific point of view from which the subject is presented. A few of these books are somewhat patronizing and show here and there a spirit of condescension as if from one not acquainted with the class of people for whom he was writing. The high school teacher has been inclined to give these books the cold shoulder, and as it seems to me very much to his detriment as well as to that of his pupils'. These books have some merits all their own. They are written for a purpose. They present a course in physics as a unit. They stick close to their text; they are books on physics from first to last. They appeal to the student from the point of view of genuine physics, not from the point of view of nature. I shall never forget the delight with which I read

the first book of this type that ever came ~~to my hand while a school~~ boy. There is something about such books that appeals to an earnest student. The product of the master hand is always attractive even though it be not always clearly understood. These books are certainly not suited for use as regular text in class, but they, like the nature books, should be at hand in the reference library and should be used with increasing freedom and delight by the student. They are written by men who know their subject more exhaustively than the high school man and are therefore able to present and emphasize those phases which are best calculated to contribute to a thorough training in this subject. It is a well known fact that the exact, technical language of science is really simpler and clearer when perfectly comprehended than is the more popular but less definite language with which the beginner is familiar. These books should aid in leading the student to prefer their language and method as his own by choice in the end. A careful and plentiful but not too exacting use of these books as an adjunct to class work will be a long, good step in the right direction.

Then there are the regular texts that are so well known and so widely used throughout the country. As most of you know, there are two books of this class which are more extensively used than all other texts on physics put together. There is no luck about this matter; these two books in the comparative judgment of teachers are the best books now published for class use. They are too well known to call for any discussion on their general merits, but a few peculiar facts about their use as sole texts may be pointed out. Strictly speaking, these books are neither scientific in their method nor are they real science in themselves. They are, rather, neatly labeled fragments of data about science. Every one knows how these fragments are fenced off into perfectly rounded paragraphs and duly labeled with the appropriate black letter headlines. One is reminded of the old fashioned method of studying geology from a set of labeled specimens carefully arranged in regular rows on a shelf behind glass doors. To study physics from a text book of this class will yield about as fruitful results as such a method of studying geology. The specimens are all right in their place; the text book is all right in its place, but you can never teach physics from such a book. Used as a compendium, it is a valuable aid to

the desired end. The merit of its omnibus character, especially in the hands of a competent teacher, is that it affords an opportunity to select courses with such variations as may best meet the needs of different classes. Without a competent teacher and a good laboratory course, these books are well nigh worthless in the hands of a class. They are as dogmatic and as precise as the most fanciful mind could imagine, but unfortunately they leave an impression on the beginner as far from the real truth in many cases as it is easily possible for words to do. Every teacher has seen the surprise of the beginner when he first discovers in the laboratory that things seldom occur in nature just as the book said it would. Great principles and laws are presented as if they were matters of simplest observation, and deductions are made from supposed experiments with a precision and absoluteness that would astonish a Newton or a Rowland. Here is the place for the large spirited, open minded, scopeful type of book, the book in which the pupil can see how great men have struggled to know the truth, the book which drives away the flippancy of hasty precision and turns cold facts into living things that are more interesting than a story. Here too is the place for the university man's book to give these facts a new setting and show that they are tools to be used for a larger purpose and a more penetrating intelligence.

It may be objected that such a variety of books is not afforded in our high schools, and the answer must be that we can not afford to be without them. The student of Latin has his reader, his grammar, and his lexicon, each of which is more expensive than a book on physics. If we do not have suitable books in physics, who is it that sets the ideals in this matter but ourselves? Teachers of physics have not yet learned to live up to their opportunities; too often they do not even know what they need to make physics teaching a success. Let us take a few more lessons from the Latin teacher and his methods. If physics is worth teaching, it is worth teaching for all there is in it.

Physics to be well taught requires not only a capacity to learn as does Latin and algebra, but it requires a high degree of ability to reason, and skill in arranging and subordinating data for the purposes of reasoning. If this power is lacking, then the memory work alone can be done which gives only the dry bones of

scientific knowledge and leaves it impotent and useless in the mind of the learner.

The discipline and culture values of Latin come from the immediate and unreasoning applications of the very thing learned to the art of speech. Culture may be defined broadly as that which determines the quality and character of one's attitude toward knowledge. In some cases we speak of the character of one's culture as musical. We say of another that he is cultured in painting, he is an artist. The degree of that culture determines the quality of his attitude toward music or whatever art may be the medium of his culture. Language is an art; it is a universal medium of culture while the other arts afford only special fields of culture. For this reason, that culture which has to do with language as its chief medium of expression is held in highest esteem by men and doubtless will ever remain so. Latin contributes directly to this culture and that largely through the simple agency of mere memoriter work. At any rate the degree of higher intellectuality required to maintain such reasoning and reflection as are needed to pursue a course in Latin is not great nor is it more than very moderately taxing on the mental capacity of the student at any one time.

On the other hand, physics if taught as a mere memoriter subject yields almost no culture values, contributes almost nothing to the linguistic capacity of the student since he is dealing with words whose real significance is hardly understood and not readily translatable into a known medium, since the only medium of translation of the rational truths of physics is reason itself. Memorizing physics or the language of physics does not even contribute to the discipline of the mind in large degree since the only discipline physics can afford is discipline in reasoning.

How then shall physics be taught to give it its true values as a study? And what must the teacher be who can teach physics to this end? These are difficult questions to answer, but if the thoughts presented above are valid, they most certainly point to some reasonably definite conclusions. The teacher of physics should be better educated for his work than at present. He should have a larger knowledge of his subject and a broad, appreciative familiarity with a large range of human knowledge in order that he may

see in the study of physics its culture and disciplinary values as well as its mere utilitarian values. He must be a person of large sympathies and unusual skill in developing the intellectual powers of his pupils.

Physics covers so wide a field, that selection is always necessary; and while great variation may appear in the selection made, the selection when it is made must exhibit unity and a definite aim. We must give up attempting to teach everything simply because it is in the text book. We must select topics and themes as will contribute in the end to the best possible knowledge of the subject with least expenditure of time and effort. We must so arrange and subordinate the matter selected as to make it possible for the student to proceed without frequently encountering insuperable obstacles and discouragements. The pupil must come to enjoy reasoning. He must learn that there is great beauty and an interest that is unique in truth based on unquestionable premises. He must be led to take pleasure in conclusions reached through his own mental processes. He must be so led as to come to a feeling of security in his own intellectual powers and to prefer truth to logic, and to know that reasoning based on evidence is the only valid reasoning. To secure all this the teacher must be one who can make physics interesting for, while memoriter work as in Latin and algebra can be secured from the pupil without interest, growth in reasoning never can; therefore, the first concern of the teacher must be to secure and maintain interest. I do not say it is a chief aim, it is not; it is only a means to an end, but it is essential to that end. More interesting material should be wrought into the course for the stimulus it will give and because interesting applications of the cold principles of physics make the study real and give it a lasting place in the mind of the learner. There are only two ways to make things stick in the mind of a pupil, one is to repeat the thing without variation till it becomes a habit of the mind. This is the method of the Latin and the algebra teacher. The other is to present the thing with such interest to the learner that his whole being responds to the act of accepting and adopting it, and with such intensity that with only one or possibly two presentations of the thing it is indelibly fixed in the mind of the pupil. This is the necessary method in all rational subjects. That it is immensely

more difficult than the other method goes without saying, but the fact remains that we as teachers often act and teach as if we had never thought of this difference.

Physics can be made to contribute very largely to language culture. I believe it possible to make physics a better culture subject so far as skill and drill in language is concerned than literature, fully equal to Latin if studied as long and as faithfully, and vastly superior to algebra in every respect. But the mere study of physics will never do this; this language culture in physics will come only under the guidance of a teacher who sees these possibilities in the subject and then holds his pupils to an excellent and increasingly refined and exact use of language to express their thoughts.

The past four thousand years of the world's history may be called the age of logic. In the civilized races, the logical faculty is highly developed. The young people of our schools are generally excellent reasoners from the point of view of mere logic. They will build up the most remarkable theories and conclusions so long as you do not meddle with their premises nor question their conclusions. But the minute you limit the premises and prescribe the conditions of the reasoning, they fall flat. This is a new capacity. Very few men in the world today can reason from prescribed premises. One of our leading university presidents has said that not one man in a thousand can reason in the modern scientific sense. Ten thousand years from now, this faculty may be common; today it is the possession of the few who are scientifically educated. We must not expect too much nor too rapid growth in this kind of development in our students. But since it is the most potent capacity with which the human mind can be endowed, it should be striven for constantly in our teaching. The philosophers of the middle ages carried logic to the sublimest heights but the fatal defect of it all was that they failed to examine their premises. This was the age when those wonderful isms and schisms of the religious world now so familiar to us were developed, and we are not through with that sort of thing yet. It should be the province of science to so train the mind that faith in reasoning from inadequate premises will be recognized as stultifying and immoral. Physics of all the sciences is best adapted to this purpose, and teach-

ing to this end may be said to contribute in a high degree to scientific culture. Physics may not equal Latin for pure linguistic training, but combined with a good course in English it should be immensely superior, because of its richer educational values. When the true educational values of physics and biology are correctly understood by the people, and teachers have learned to teach these subjects for all there is in them as Latin and algebra are now taught, we shall see a popular and permanent reversion to these noble studies; and a fuller, richer, rounder training for life's activities will be the common possession of our high school graduates.

ECONOMIC ZOÖLOGY.

BY FRANKLIN W. BARROWS.

Some one has said that economic zoölogy is the study of animals from the standpoint of dollars and cents. It is this and more; for it includes the consideration of all the influences exerted by animals for the good or the ill of man, their reputed master. The object of the science, or perhaps it should be called the art, is the complete realization of our dominion over animals. The literature of the subject is found scattered through the reports of the various scientific departments of all governments. Probably a very fair idea of the present state of the subject can be obtained by consulting the reports of our own government.

Of the actual beginnings of economic zoölogy we know absolutely nothing. There is considerable evidence that the cave-dwellers used a variety of animals, including fishes, for food, but there is nothing to show that these primitive folk had established friendly relations with any of their animal neighbors. They clothed themselves in the skins of beasts and made rude tools from bones and horns, but it was evidently reserved for a later race to begin that long campaign of education which has given to us our domestic animals. With the taming and controlling of the

lower animals man himself progressed from barbarism to civilization, and it may safely be assumed today that the culture of a race is in direct proportion to their progress in the utilization and mastery of the animal world. In our brief consideration of man's present attainments along this line, it will be well to speak first of his mastery of domestic animals and then, of his dominion over untamed animals.

We know that the most familiar animals of the house and farm were first subjected to man somewhere on the Asiatic continent, but their origin and the date of their subjection are, in practically every case, mysteries beyond the power of the historian to solve. Certain it is, however, that man early acquired the art of improving the primitive stock by selective breeding, and thus began to develop under his own guidance the many varieties of breeds and strains that obtain today among all our domestic animals. Thus the exceedingly diverse varieties of pigeons, dogs, horses, cattle, etc., are the results of human design slowly and deliberately worked out in accordance with natural laws. Many of these varieties, such as the pouters, tumblers and fantails, among pigeons, and the poodles and bull-terriers among dogs, have been bred merely to suit the caprice of the fancier. In the majority of cases, however, the motive of the breeder has been purely economic and we of this century are literally "the heirs of all the ages" in our possession of so large a group of animal species won from their native state and developed to supply so perfectly so many of our needs. The dog has been adapted to the requirements of hunting, herding, policing, drawing burdens, and even of serving as the companion of man. Other animals have been bred for hunting and fishing—such as the ferrets, otters, cormorants, owls and falcons. Fifty years ago there were a half dozen breeds of chickens in the United States. Now there are over 100. At the same time the yearly number of eggs per hen has been increased from seventy-five to one hundred and seventy-five, according to Prof. G. P. Roberts, of Cornell University. The poultry breeder has produced varieties excelling also in quantity and quality of flesh and plumage, respectively, while he has utterly conquered the migratory instinct which was so strong in the original stock of our ducks, geese, and other fowls. The domestic pig weighs four

times as much as his wild relative, and has developed remarkable qualities of mind and body from his association with man. Among wild cattle the female produces just enough milk to suckle her calf, while the domestic breeds most famous as "milkers"—the Holsteins and Ayrshires—will yield their own weight in milk every twenty or thirty days. Both the quality of the milk and the period of lactation have also been immensely influenced by breeding. Other varieties of cattle, as the Durhams and Herefords, are bred for beef, while the Devons are noted for their excellent qualities as yoke oxen. Our modern horses, also, illustrate in many ways the art of the breeder. Originally serving man as a pack animal, the horse soon became the indispensable companion of the traveler and the merchant, and in course of time acquired a place of inestimable importance in warfare. The steed of the Norman knight was the noblest horse that the world had ever seen, and from him are descended the finest draught animals of the present day. Neither the Norman knight, however, or any of his contemporaries ever dreamed of the excitement of the modern race track, or fancied that the prize horses of the Derby would win their laurels by whisking a light-weight jockey around the circle in a ball-bearing sulky, and not, forsooth, by carrying a lusty baron and two hundredweight of armor in the tournament. Both in England and in this country the most careful attention has been given to increasing the speed of the horse. Seventy-five years ago the running record was three minutes. In 1865 Legal Tender ran in 1:44, a record that is equalled or excelled on every race-course in the country today. In 1843 a trotting record of 2:30 was established. In 1894, fifty years later, the number of horses on record that had trotted a mile in 2:30 or less was over 7,500, and rapidly increasing. Twenty-three horses at this date had records ranging from 2:04 (Nancy Hanks) to 2:10. Thus within the past century the American horsemen have developed a distinct breed of horses, and all by the persevering application of the principles of artificial selection for four or five successive generations. At the same time, we have not neglected the perpetuation and improvement of other serviceable breeds of horses, adapted to the plow and the road. The mule, a hybrid that owes its existence to the enterprise of the stock-breeder, is one of our

national resources, and St. Louis has the proud distinction of being the greatest market on earth for this animal.

While the present is an era of great accomplishments in the improvement of domestic animals, it must be admitted that few if any new species are being won from the wild state in this or other countries. The list of domestic animals remains about what it was two centuries or more ago; in fact, the falcon and other species that were once so generally employed in the sport of "hawking" have been allowed to return to the wilderness—the only case, according to Shaler, in which man has abandoned a species once domesticated. It is said that the camel is gradually retiring from active service for man, but it is not likely to be entirely superseded for many years to come. Even the horse and the dog are of less economic importance now than when they helped man to explore and colonize the vast wilderness of a few generations ago.

If our progress in the arts and industries has somewhat depreciated the value of a few of our domestic animals it has more than compensated for this depreciation by discovering new uses for animal products and thus vastly extending the utility of the animal kingdom as a whole. This age excels all others in the variety and extent of the services derived from animals. No animal product is wasted. Indeed, every item in the inventory has its market value today. It is not surprising, therefore, that the agricultural world devotes its best efforts to the problems of livestock. Our experiment stations in this and foreign countries, are investigating the food of farm animals, in order to discover the proper dietary for the work-horse, the milch-cow, the porker, or the laying-hen. The agricultrual chemist is studying the effect of different diets on the quality of manures produced and utilized on the farm. The Bureau of Animal Industries, an indispensable adjunct to the other activities of our United States Department of Agriculture, is investigating the vast field of diseases of domestic animals and experimenting on the means of preventing or curing them. Results of momentous significance have been attained in the study of trichina, Texas fever, hog cholera, tuberculosis, sheep-scab, tapeworms of poultry, and a host of other parasitic and infectious diseases which constantly prey upon our useful animals. It would be

interesting to recount a few of the methods used and the results obtained in these investigations, if the limits of this paper would allow. Suffice it to say that the means employed and the money expended in these researches have been amply justified by the results, not only in our own land, but the world over.

Twenty years ago the British kingdom was losing a million sheep annually from the disease called "liver-rot," and in the years 1879-80 the loss was over three million. The investigations of the royal commission charged with the study of this disease showed that it was due to a parasitic worm, and pointed the way to remedial measures that have materially reduced the pest and restored to England millions of dollars. A few years ago the British public became aroused to the importance of checking tuberculosis in cattle. A test of Queen Victoria's herd at Windsor Castle showed that ninety per cent of the animals were afflicted with the disease and indicated the necessity of an immediate campaign to save the cattle interests of the island. Today the English people are comparing statistics and they find that the British cow is yielding thirty per cent less milk than the cow of Denmark on the same quantity of food. Such instances serve to show the value of the scientific and statistical methods by which every country is extending its animal resources.

In our own country the total value of all farm animals in 1896 was reported at $1,997,000,000. Four years later, in 1900, $2,213,000,000. In 1891 our exports of farm products alone amounted to $950,000,000, and made up sixty-five per cent of our entire export trade. Of this amount, $250,000,000 worth consisted of animal products. To protect ourselves and our customers, the United States government, during this year, inspected a million and a half of cattle for Texas fever, and vaccinated thousands of cattle for black-leg. Out of a total of five million cattle inspected for various diseases, 12,500 were condemned. Out of 24,000,000 hogs inspected, 80,000 were condemned. These are but a few statistics showing the enormous extent of our animal industries and the degree to which we have developed our system of intelligent supervision.

Our government exhibits commendable enterprise, also, in the introduction and encouragement of new species of domestic ani-

mals. The establishment of the reindeer in Alaska, while its ultimate success is questionable, has proved of considerable value on several occasions. The government is introducing the Angora goat into regions where it promises to add materially to the resources of the farmer. The last report of the Secretary of Agriculture turns our attention to the development of the animal resources of our island possessions. In Hawaii, for example, it is reported that live hogs sell for ten to seventeen cents per pound, chickens for $15 per dozen and eggs for forty to fifty cents per dozen, all being in the category of luxuries. It is proposed to increase these products in the islands until they can be sold as cheaply as the common foods.

We will now consider that vast field of economic zoölogy including all those animals directly beneficial or injurious to the human race, which have not been domesticated to any extent. We shall see that in this field, also, the present age is making great conquests—and some sad mistakes as well. A mere enumeration of the animals in question would occupy more time than can be spared, and the characterization of their economic features must therefore be very brief and imperfect.

You have probably heard the ancient saying that Amsterdam is built on herring bones, and we could all of us name less conspicuous communities of our own acquaintance whose existence depends on fisheries and related industries. The British boast that every acre of water about their island is more productive of wealth than so much English soil. The German ocean produces annually eight to twelve pounds of fish per acre, or a billion to a billion and a half of pounds in all, and the German government is laboring to increase this output several fold. The sturgeon fisheries of the Volga river employ a hundred thousand men. Two years ago the fisheries of the United States yielded a return of forty millions of dollars, and the oyster business alone was worth fourteen millions, and yet the country had to import fishery products to the value of six million dollars, most of which might as well have been produced in American waters. Every one knows something of the methods and results of the work of our national and state fish commissions, to whom is due most of the credit for the prosperous condition of our fisheries. Not only do they raise fish artificially

but they learn how to combat successfully some of the diseases and enemies that prey on our food fishes. America has the distinction of leading the world in the rearing and protection of fish. To show what one state can do in one year it may not be amiss to refer to the report of the New York state fish commission for 1898. In this year the state fish-car made forty-six trips, distributing thirty-five car loads of young fish throughout the state, and fifty carloads of fish were allowed to remain in the hatcheries for the next year's planting. The state expects to restock Lake Ontario with whitefish, and for this purpose hatched twenty million fry in one year. Our fish and game commissions frequently render good service by suggesting appropriate legislation and correcting faulty laws.

And now, to change the subject again, we shall not find in the whole range of animals another class of such power for good and evil as the insects. The time was, not many years ago, when the professional entomologist was dubbed a "bug-hunter" and regarded with undisguised contempt by the *"practical"* farmer and man of affairs. But the despised bugs kept rolling up accounts against our people and collecting them regularly, annually destroying agricultural products valued at $100,000,000 to $300,000,000. Our people set the bug hunter to devising some sort of relief from the insect plague, and the science of economic entomology was brought from Europe to America. Like many other things introduced from the old world, it has developed beyond all previous bounds and now America leads the world, without a rival in the science of applied entomology. The present indictment against insects consists of five counts and is well enough expressed in the words that I shall quote from Dr. Howard, the United States Entomologist.

"Insects are injurious:

1. As destroyers of crops and other valuable plant life. 2. As destroyers of stored foods, dwellings, clothes, books, etc. 3. As injuring live stock and other useful animals. 4. As annoying man. 5. As carriers of disease."

Another quotation shows the possibilities of these pests when acting in the first named role:

"At the present time almost every cultivated crop has not only its thousands upon thousands of individual insect enemies, but it is affected by scores and even hundreds of species. A mere

tabulation of the insect enemies of the apple already recognized in this country shows 281 species, of clover 82 species, and of so new a crop as the sugar beet 70 species. The insects of the vine, of the orange, of the wheat crop, and, in fact, of all of our prominent staples, show equally startling figures."

In another place Dr. Howard quotes statistics showing that half the cattle received at the Union Stock Yards of Chicago in 1889, were afflicted with the ox bot fly, or ox warble, resulting in an actual loss of over three million dollars in six months from that one insect alone. Instances of insect ravages might easily be multiplied *ad infinitum*. The only redeeming feature of this situation is the wonderful industry of our scientists, who in all parts of the world, have studied the problems of fighting and exterminating the foe. The public has been educated, also, in a few of the fundamental principles of economic entomology, especially in regard to the value of birds in combating insects. We are becoming more than ever impressed with the dangerous character of flies and mosquitoes. Experiments in the eradication of mosquitoes have been carried on in many parts of the country. We all know what has already been done along this line in some tropical regions. Reference will be made in another paragraph to the extraordinary battle waged in California against the scale insects. Indeed, we may say, in summing up this part of the subject, that no warfare was ever more scientifically waged than the present warfare of civilization against noxious insects, allowing, of course, that there is still ample room for improvement.

(*To be concluded in June.*)

THE VALUE OF MAKING AN HERBARIUM.

BY JOHN E. CAMERON,

Instructor in Botany and Zoology, Cedar Rapids (Ia.) High School.

There should be three kinds of work required in an elementary course in botany. These three kinds are: *(a)* General observations in the field. Pupils should be familiar with the common names of plants, the natural conditions under which they grow, their rela-

tions to their surroundings, to animals and to each other. *(b)* Work in the laboratory, consisting of the study of plant structures, plant function and plant physiology. There should also be experiments with plants to determine the various conditions under which seeds will grow and to determine how the plants may be affected by light and darkness, heat and cold, moisture and dryness. *(c)* Work in recitation room where the facts observed in the field and the laboratory may be classified and systematized, where the practical knowledge relating to plants may be made more prominent. These three kinds of work, together with the study of a good elementary text on the subject, should prepare the pupil to get much useful knowledge out of the plant life surrounding him.

But the methods employed in getting the work done have not proved satisfactory. The laboratory work and the recitation room work have been carried on without the field work. Today the unsatisfactory condition exists in the study of elementary botany because an attempt has been made to introduce botany into the high school from the standpoint of the college. The pupil is expected to plunge directly into laboratory work, to study minute structures of plants, and to consider many of the advanced problems before he has been given an opportunity of learning the elements of the subject.

The topics presented should be within the range of the pupil's understanding. He must know the names and have practical knowledge of the various herbs, shrubs and trees, so that he may know which are useful and which are harmful to mankind. He must have a knowledge of the conditions under which each plant grows, and the way in which each plant adapts itself to its environment. He should know how pollination is accomplished and how seeds are distributed. When the pupil is familiar with the many forms of plants around him, he is then fitted to take up the more advanced problems presented by the subject.

But how is the pupil to become familiar with the plant life around him? Can he do so by spending all his time with minute structures, with cultivated plants, or with leaves, flowers and seeds, brought into the laboratory without his having any knowledge of where they came from and of the conditions under which they grow? The pupil must go outside of the laboratory and see the

tree or other plant growing as a whole in its natural habitat. The entire life history of the plant must be worked out if the knowledge obtained is to be of the most use to him.

The laboratory work is necessary, but the field work must be done if desired results are accomplished. It is no trouble for the high school teacher to get the pupils to go into the laboratory or recitation room for an hour or more a day for work; but when he attempts to have the pupils go into the field to learn where and how plants grow, he has a difficult problem to solve. The teacher has other classes and he cannot leave the school room during school hours. The pupils are retained there for the same reasons, and only the more interested ones will go after school hours. The teacher is compelled to have some method of getting all the class out into the field. Field trips are planned, but many of the less interested pupils will find an excuse for not going, and those that do go will not get so much out of the work as they would if some of the plants were collected and kept for future study. If a teacher requires a collection of at least twenty-five specimens of plants, he will create an interest in the field excursions. The pupils will all want to learn the names of the different plants, where each plant grows, the character of the plant, everything about it, for he may have to make a record of it in his plant herbarium. The teacher is thus able to give proper credit for individual work—the kind of work that will be of the most use to the pupil in later life.

The making of the herbarium is not for the sake of the herbarium, but it is used as an incentive to get the pupils out into the field in order that all phases of plant ecology and plant life may be considered. Thus the field work is carried on hand in hand with laboratory and recitation-room work.

Much valuable time is often wasted in learning the technical terms required in plant descriptions. These terms must be learned so that the pupil may be able to use intelligently a simple plant key such as the "Key to Native and Cultivated Plants" by Prof. Macbride of the State University of Iowa.

Every herbarium should contain a list of the more common terms and their definitions arranged in such a way as to enable the

pupil to learn them in the shortest possible time—an important item in a brief course in botany.

While the pupil is learning to describe plants in the laboratory, the terms relating to the root, stem, leaves, flowers and seed can be placed before him in the form of a "Key to Plant Description" as a general outline. The teacher can readily supply the other necessary terms to describe the plant in hand, and thus the work of the teacher will be lightened and the pupil gain interest and rapidity in writing the plant descriptions necessary for his herbarium.

The knowledge gained by the comparison of plants and the arrangement of these in their proper orders or families can be obtained in no other way as easily as by making a plant collection. Systematic botany should not be eliminated from the elementary course of study if we wish the pupil to have a general knowledge of the subject.

Objections have been made to the making of an herbarium because the work is largely mechanical. The high schools of today are in need of more manual training, not less of it, because it furnishes an outlet for the physical energy of the pupils. The writer has had several years' experience in both methods of presenting the subject of modern botany, and has found the best results obtained when an herbarium was made.

LABORATORY STUDY OF A RIVER.

BY IRVIN C. HATCH, PH. D.

Cogswell Polytechnic College, San Francisco, Cal.

As rivers do the greater part of the sculpturing of the earth's surface, the study of their action forms one of the most important topics of physical geography. But a river that is making perceptible changes is rarely accessible to a class, and the natural processes are too slow for the river's history to be readily understood by the beginner. The entire development of a river valley can be shown by a simple laboratory experiment, which may easily be prepared in any school giving elementary physical geography.

I have given this experiment three successive years with gratifying results, and as I have never seen it described, I judge that other teachers may be interested in a description of its preparation.

A strip of roofing tin, 28 inches wide and ten or twelve feet long, with flat soldered seams, and painted on both sides to prevent rusting, was procured at a cost of about $1.50. Sides four inches high were turned up, making a trough twenty inches wide and four inches deep. The ends should also be closed, either by binding up the tin and soldering the joints, or by inserting a wooden end and tacking the tin to it. A notch or spout can be provided at the lower end so that the overflowing water may be carried to a wastepipe. The trough is laid upon some boards or a table, so arranged as to give a slight slope, three or four inches, to the lower half, and a greater slope, of six to ten inches, to the upper half. The tin will readily sink into this position, making a slight kink at the bend.

Next, the trough is filled with sandy or light soil, spread out nearly smooth but not packed, and leaving a space of about two feet at the lower end. Then a small stream of water is allowed to flow into the upper end, and to choose its own course down to the space left vacant at the lower end, which, as it fills, becomes a bay or gulf, checking the flow of the stream and allowing the deposit of sediment. Here splendid deltas or alluvial fans are soon built up. The action of waves and tides upon deltas and sand bars may be studied by agitating the water in this space. A jetty can also be quickly built by inserting two strips of glass or thin wood near the mouth.

The lower portion of the stream ages rapidly, and soon develops meanders and flood plains. The steeper part has the gorges formed by swift streams, and at first has the waterfalls, lakes and other characteristics of young rivers. A permanent waterfall will be formed if a layer of clay has been placed beneath the surface of the soil. The effect of material on the slope of the banks may be illustrated by using various kinds of soil. As the trough is flexible, a gradually rising or sinking may easily be produced, and its effect on the river observed.

Usually I have devoted about three lessons to this experiment,

allowing the water to run continuously in the interval. But the exercises may be varied and increased indefinitely, according to the time at the disposal of the class.

AN EXPERIMENT ON SLIPPING FRICTION.

BY C. E. LINEBARGER.

Sliding friction alone receives attention in most high school laboratories of physics. The phenomena of slipping friction are, however, quite common, as in the transmission of power by belting, etc. As the laws of slipping friction are different from those of sliding friction, both deserve attention.

The experiment on sliding friction consists in finding the ratio of the driving force to the load and comparing this with the amount of surface between the belt and cylinder. A wooden cylinder, a glass bottle, or a tin can is clamped firmly with its axis horizontal about 80 cm. above the table, and a stout and hard cord slung over it. To one end of the cord is attached a spring balance, reading up to 4 pounds or 2,000 grams, and to the other a scale pan. If the balance be pulled along a horizontal line tangent to the upper side of the cylinder, the scale pan is lifted and the cord is in contact with just one-quarter of the cylinder. The scale pan should be loaded in all trials so that the reading of the spring balance is near its maximum, the error of reading being thereby minimized. Of course, it is necessary to apply a correction for the balance when in a horizontal position, as it has been made to read correctly only when right side up and in a vertical position. The load is raised steadily several times and the balance reading taken, a mental average being struck.

The balance is now pulled vertically downwards so that two quarters of the cylinder are in contact with the cord. A correction has to be applied here also to the balance reading, if the balance be used upside down. The balance is now pulled horizontally so that three quarters of the cylinder are in contact with

the cord, and then vertically upwards until the whole cylinder encircled with the cord.

These operations are repeated with five, six, etc., quarters of the cylinder in contact with the cord until the driving force becomes over ten times as great as the load.

The data are tabulated under the following heads: (1) Number of quarters of cylinder encircled by cord; (2) Load; (3) Balance reading; (4) Driving force; (5) Ratio of driving force to load. A curve is platted with "Number of quarters" on the axis of abscissas and "Ratio of driving force to load" on the axis of ordinates. The curve is almost straight up to three or four quarter turns; it then rises more and more rapidly. Such a curve is very instructive and its full interpretation should be insisted upon.

A FEW ARTICLES THE TINNER CAN MAKE FOR THE SCIENCE DEPARTMENT.*

BY W. E. BOWERS.

Seattle, Wash.

Water bath, sheet copper, 12"x9"x3", provided with drain and ten holes with covers as follows: Three 3", and two 2½" for

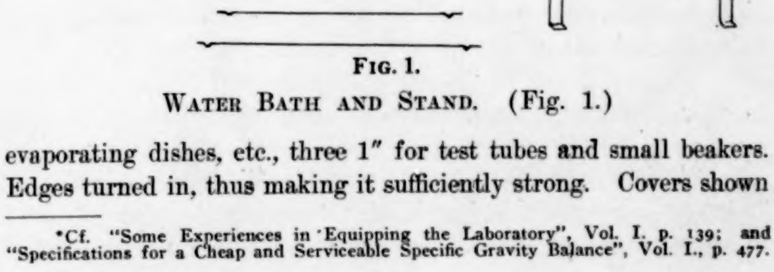

FIG. 1.

WATER BATH AND STAND. (Fig. 1.)

evaporating dishes, etc., three 1" for test tubes and small beakers. Edges turned in, thus making it sufficiently strong. Covers shown

*Cf. "Some Experiences in Equipping the Laboratory", Vol. I. p. 139; and "Specifications for a Cheap and Serviceable Specific Gravity Balance", Vol. I., p. 477.

in section. Larger covers pressed, hammered or spun copper; small covers, piece of sheet copper weighted with solder or lead.

Stand of sheet or hoop iron, about 8″ high if to be used over a Bunsen flame.

Made in Marinette, Wis., for $1.75. List price of similar ones, $3 to $8.

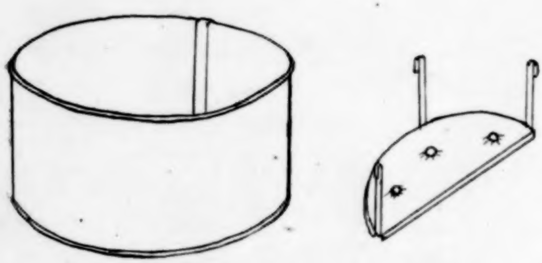

FIG. 2.

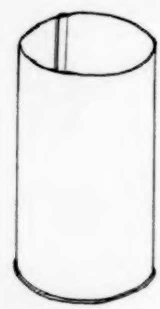

FIG. 3.

PNEUMATIC TROUGH. (Fig. 2.)

Pneumatic trough, galvanized iron, double seamed and soldered inside; heavy wire at top; 12″ diam.; 6″ deep. Shelf 5″ wide, edges turned down, held 3″ below top of trough by three lugs; three half-inch holes punched *upward*. Simple, durable, useful for many other purposes.

Made in Willmar, Minn., eight for $4. A smaller size, 10″x5″, made in Marinette, Wis., ten for $3. List price of similar ones, $1 to $3 each.

CALORIMETER. (Fig. 3.)

Calorimeter, roofing tin, 5″x3″, soldered *inside*, weight about 95 grams. Not suitable for all laboratories, as they must be kept in a dry place and placed on a radiator or before a register after

using. Made in Willmar, Minn., eight for 60 cents. List price of brass calorimeters, 60 cents each.

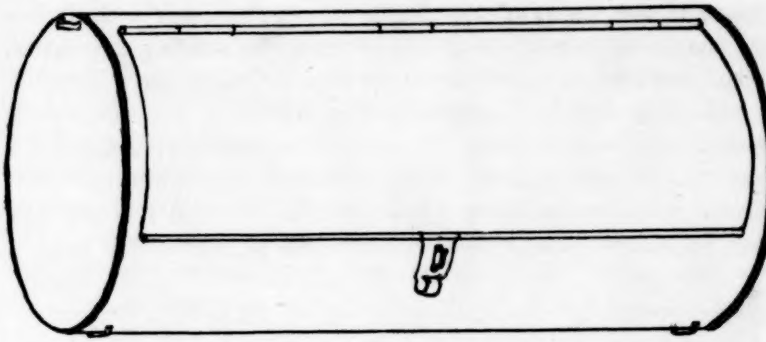

FIG. 4.

VASCULUM. (Fig. 4.)

Vasculum or collecting box, heavy tin, 18″x9″x5″, cover 16″x6″, wired and soldered, hinged with clasp and staple; loops for carrying strap. Made in Northfield, Minn., for $1.25. List prices for various sizes, 60 cents to $3.

A LABORATORY EXPERIMENT WITH WIRELESS TELEGRAPHY.

BY J. J. MARSHALL.

Superintendnt of Schools, Romeo, Mich.

A system of wireless telegraphy, made and operated by the students of my physics class, constituted one of the most interesting and profitable experiments of the year. From articles found in the current numbers of the periodicals in our reading room, notably the *Scientific American,* Vol. 87, No. 1, the students made the entire outfit from materials already in the laboratory. The making of or setting up the apparatus I consider a valuable part of the experiment. The apparatus is so simple and inexpensive that it may easily be made in any laboratory. It usually happens that the most efficient apparatus is the most expensive, but such is not the case here. This form of apparatus, though the acme of

simplicity, was the form first used by Marconi in transmitting the signed "S" across the Atlantic.

I shall describe the system as it was finally used by my students, though many of the details may be changed without impairing its efficiency. Fig. 1 represents the sending apparatus; Fig. 2 the receiver, and Fig. 3 a detailed outline of the coherer.

In Fig. 1 *B* is a battery of two potassium dichromate cells attached to the primaries (*P* and *P'*) of an induction coil. *S* and *S'* are the terminals of the secondary wire. They are connected by an insulated wire (size about No. 16) with a switch, *Sw.*, and key *K*, in series. The switch is *always* open and is used to

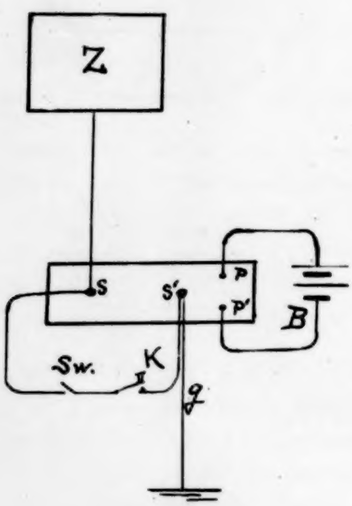

Fig. 1.

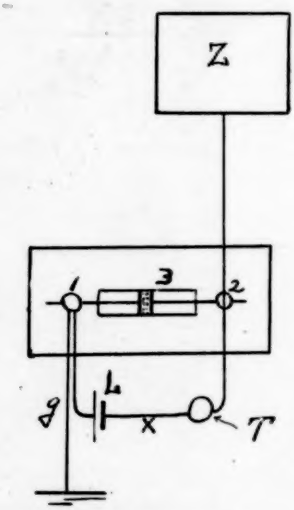

Fig. 2.

regulate the length of the spark, in our experiment, $^1/_{16}$ inch. The key is used to give the signals of the Morse code. From *S*. a vertical wire leads to the zinc plate (8x10 in.), which was placed about ten feet above the floor and facing a similar one on the receiver at the opposite side of the room and at the same height. *S'* was joined to a steam radiator, thus making a ground connection.

In Fig. 2, *Z* represents the vertical wire or antenna, as in

Fig. 1, and is connected to binding post 2. The binding posts 1 and 2 should have two set screws each. Post 1 was connected with a steam radiator, thus completing the earth connection through the boiler. Posts 1 and 2 were joined by the coherer, which I shall explain later. They were also connected by a Leclanché cell, *L*, and telephone receiver, *T*. The coherer, the telephone receiver, and the cell are thus in series.

Fig. 3 represents the coherer. We had no binding posts of the kind known as double wood screw posts, largest size, to receive the brass plugs mentioned in the *Scientific American*. The students therefore made the coherer as follows: They took a polished hard wood base found in the laboratory and fastened four binding posts as indicated at 3, 4, 7, and 8. Posts 3 and 4 were about three inches apart; 7 was connected to 3 by a copper wire

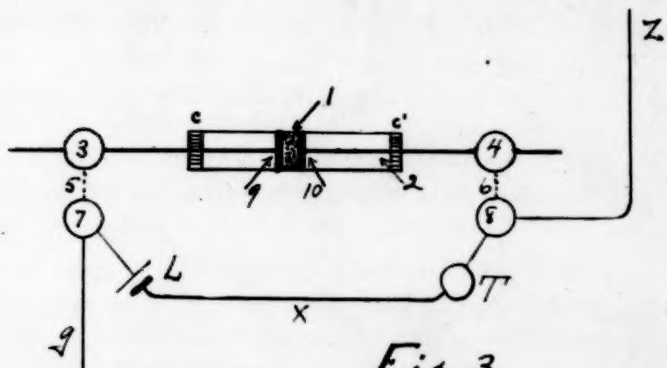

Fig. 3.

underneath the base; likewise 8 was connected to 4, thus practically making double binding posts. The students took two copper disks, 9 and 10, three mm. in diameter, and to each one soldered a copper wire two inches long. They selected a glass tube, 2, which would fit easily over these. Disk 9 was inserted and held in place by a cork, *c*. Then a small quantity of carbon dust, obtained by grinding a piece of electric light carbon, was placed in the other end, and the other disk, 10, inserted and held in place by the cork, *c'*. Enough carbon should be used to make a layer about $^1/_{16}$ in. between the disks at 1. Then fasten one wire in binding post 3, and make all connections as indicated,

leaving the wire that passes through 4 loose. While holding the telephone at the ear, push the wire in gently with a slight twisting motion, compressing the carbon dust till the maximum sound is heard. Then set the screw in post 4 and the instrument is ready to use. As the Morse signals are given at *K*, they can easily be differentiated by the tones in the receiver, *T*. The Hertzian waves cause a varying current in the circuit of which the receiver is a part, and these variations cause a tone to be produced in the telephone.

NOTES:—The ground connections may be made by leading the wires outside the building, and after fastening the end to a piece of zinc one foot square, burying it in the ground.

It would be more convenient to insert a switch at *X* to break the circuit when not in use.

In the absence of an induction coil, the static machine may be used.

ANALYSIS OF POTASHES.

BY WILHELM SEGERBLOM.

Instructor in Chemistry, The Phillips Exeter Academy.

Some time ago I needed a strong cleansing agent, and the first thing that came to hand was some of the so-called "potash lye" on the market. This did not show the expected alkaline activity, but acted more like salsoda. An investigation of this class of substances suggested itself therefore as a practical problem for my advanced students.

Three different brands of so-called "potashes" or "lyes" were analyzed qualitatively and all were found to give a strong sodium flame, and a careful search for the potassium flame failed to show a trace of this metal. None of the other bases were present. The usual analysis for acids showed the presence of carbonic acid, sulphuric acid, and hydrochloric acid. The deliquescence of all three mixtures showed the probable presence of a hydrate. The analyses for different cans of the same brand were far from constant, showing probable carelessness in the mixing of the ingredients. The carbonate was assumed to be present with its water of crystalliza-

tion because the crystalline lumps gave a considerable test for carbonic acid and the powder showed only a trace. The qualitative results were as follows:

	1st Can.	2nd Can.
Brand No. I.	$NaOH$ $Na_2CO_3 . 10H_2O$ $NaCl$	$NaOH$ ——— $NaCl$
Brand No. II.	$NaOH$ $Na_2CO_3 . 10H_2O$ $NaCl$ Na_2SO_4	$NaOH$ $Na_2CO_3 . 10H_2O$ $NaCl$ ———
Brand No. III.	$NaOH$ $Na_2CO_3 . 10H_2O$ $NaCl$ Na_2SO_4	$NaOH$ $Na_2CO_3 . 10H_2O$ $NaCl$ ———

Methods were then devised for the quantitative analysis of the above mixtures. In those potashes that had lumps of hydrate or carbonate, the lumps were crushed in a mortar and the resulting powder was shaken with the rest of the potash in order to get fair samples to work with; this shaking was done in a sealed jar to prevent absorption of moisture from the air as far as possible. These quantitative methods were devised largely by the students themselves, but approved by the instructor before actual work was begun.

DETERMINATION OF CARBONIC ACID.

Fifty grams of "lye" were placed in a 500 c. c. Florence flask fitted with a two-hole rubber stopper, thistle tube, and delivery tube to pneumatic trough. 150 c. c. of water were added and the lye allowed to dissolve. Hydrochloric acid was added in sufficient quantity to drive off all the carbon dioxide which was caught in an inverted bottle of two to three liters capacity. From the volume of the gas collected we deducted the volume of acid added to get the volume of carbon dioxide. From this and the weight of 1 c. c. (0.00193 g) it was easy to get the weight of carbon dioxide; the volume of gas collected was not reduced to normal temperature and pressure as the error of this omission was less than one per cent in the final result. The proportion,—molecular weight of $Na_2 CO_3 . 10 H_2O$: molecular weight of CO_2= gram weight of $Na_2 CO_3 .10 H_2O$ taken: gram weight of CO_2,—gave us a number that needed only to be multiplied by 2 (because

50 grams lye were used) to give the per cent of salsoda in the sample started with. The volume of the gas caught varied from 200 c. c. to 1500 c. c. in different determinations. The liquid left in the flask was saved for the sulphuric acid determination.

DETERMINATION OF HYDROCHLORIC ACID.

A convenient amount of "lye" to start with seems to be 10 grams, though determinations were made with as much as 20 grams and as little as 5 grams. The lye was dissolved in water and nitric acid was added in excess to drive off the carbonic dioxide. Silver nitrate solution was then added in excess and the precipitated silver chloride filtered through a dried and weighed filter paper. The chloride was dried to constant weight and from the proportion,—molecular weight of AgCl: molecular weight of NaCl=gram weight of AgCl: gram weight of NaCl,—we got a number which needed only to be multiplied by 10 (if 10 grams of lye were started with) to give the per cent of sodium chloride in the sample. One student modified this by igniting the filter paper in a porcelain crucible and heating to constant weight to get the weight of silver chloride, but the method detailed above gave results consistent with the rest of the analysis.

DETERMINATION OF SULPHURIC ACID.

The liquid remaining in the flask after the carbonic acid determination, was washed into a beaker and if not distinctly acid to test paper it was rendered acid with more hydrochloric acid. This solution now contained sodium chloride, sodium sulphate and a little hydrochloric acid; it was warmed a little and barium chloride solution was added till no more barium sulphate was precipitated. This was allowed to stand till the barium sulphate settled and left a clear liquid, after which it was filtered through a dried and weighed filter paper, the last traces of preciptate being washed from the beaker by the wash bottle. The precipitate and paper were dried to constant weight and from the proportion,—molecular weight of $BaSO_4$: molecular weight of Na_2SO_4=gram weight of $BaSO_4$: gram weight of Na_2SO_4,—we got a number that

needed only to be multiplied by 2 (because 50 grams of lye were used) to give the per cent of sodium sulphate in the sample.

DETERMINATION OF THE HYDRATE.

The percent of sodium hydrate in each sample was obtained by adding together the percentages of the other substances found present and substracting this sum from 100.

The following table shows results actually obtained:

	1st Can.		2nd Can.	
I.	NaO H	82.9%	NaO H	90.6%
	$Na_2 CO_3$. 10 $H_2 O$	5.3%	Na_2CO_3. 10 H_2O	0.0%
	NaCl	11.8%	NaCl	9.4%
		100.0%		100.0%
II.	NaO H	35.8%	NaO H	61.0%
	Na_2CO_3. 10 H_2O	37.5%	Na_2CO_3. 10 H_2O	36.9%
	NaCl	4.9%	NaCl	2.1%
	$Na_2 SO_4$	21.8%	Na_2SO_4	0.0%
		100.0%		100.0%
III.	NaO H	50.2%	NaO H	52.1%
	Na_2CO_3. 10 H_2O	37.5%	Na_2CO_3. 10 H_2O	40.8%
	NaCl	7.7%	NaCl	7.1%
	Na_2SO_4	4.6%	Na_2SO_4	0.0%
		100.0%		100.0%

In some cases the percentages are reasonably constant; in others the differences are far greater than the known liability to error on the part of the individual workers. This leads to the inference that the ingredients were poorly mixed, as in Brand No. 1 where considerable salsoda was found in one can and none in the other, or that crude materials of varying compositions were used, as in Brand No. II, where the sodium sulphate and carbonate in the first can together equal the sodium carbonate in the second can.

As indicated in my communication to the January number of School Science these mixtures are very satisfactory to work with because the acid radicals present are those that first year students have become most familiar with and for which they are in a position to devise methods for determining quantitatively; incidentally

those acid radicals that are less familiar and cause considerable trouble in quantitative methods are absent; and finally the practical application of chemical knowledge recently obtained to substances actually used in the home and shop appeals strongly to ordinary students, and a problem like the above links the science and theory of the class room to the experiences in every day life.

NOTES ON RECENT ADVANCES IN ZOOLOGY.

BY MAURICE A. BIGELOW.

Department of Biology, Teachers' College, Columbia University.

It will be the aim of the notes of which this is the beginning of a series to present brief abstracts of the most important recent publications which are likely to be of interest to science teachers in secondary schools. Particular attention will be given to interesting papers which appear in foreign journals to which high school teachers outside of the great cities rarely have access. In all cases it will be attempted to avoid the extremely technical special investigations in order to devote our space to work of general zoölogical interest, and especially to results which are directly related to topics commonly involved in high school zoölogy.

Digestion in Amoeba. H. Mouton has isolated a species of amœba by cultivating on gelatine plates and making sub-cultures after the method employed in bacteriology. Associated with the amœbas was bacillus coli communis, which served as food. Large numbers of the amœbas were developed; and a proteolytic ferment resembling trypsin, but intermediate between that and pepsin in action on proteids, was extracted from the cultures. This seems to be the digestive agent at work in the food vacuoles. That the enzyme was not a product of the associated bacteria, is shown by the failure to extract it from pure cultures of the bacteria without amœbas. (Annales de l'Institute Pasteur, Vol. 16, pp. 457-509, 1902).

Salivary Digestion in Stomach. Observations made at Harvard in 1898 by Dr. W. B. Cannon on movements of stomach and intestines of cats, as seen by means of Röntgen rays and fluorescent screen after bismuth subnitrate had been given with the food, gave evidence that peristaltic waves do not pass over the fundus of the stomach. Conse-

quently food in this part is not rapidly mixed with gastric secretions, and salivary digestion may be supposed to continue for some time after food enters and before the action of the saliva is interrupted by the gastric juice. Further studies by Cannon and Day (Amer. Jour. Physiol., Vol 8, Feb., 1903) show that after dry starchy food mixed with saliva has been digesting one hour in the stomach of cats the contents of the fundus have an average of twice the sugar found in the pyloric end. When the food is given with liquids more rapid mixing takes place, as might be expected.

Rejuvenation in Paramoecium. One of the most interesting of recent physiological investigations is that by Dr. Calkins of Columbia on the life-cycle of Paramœcium. He has aimed to test the widely accepted view that the life-history runs in cycles, the animals becoming weakened after a certain number of successive binary division, and that conjugation is necessary to restore ("rejuvenate") the lagging functions, otherwise the animals die. Starting with an individual in 1901, and isolating the individuals of each successive generation, a continuous line of descendants has been kept under obervation for twenty-three months, when the series ended with the death of all individuals of the 742nd generation. Four times in this series of generations the animals became weakened and were revived by artificial means, such as, mechanical agitation, beef-extract, various salts; and with such stimulation the life history was prolonged for 742 generations without conjugation, instead of the usual life-cycle of about 150 to 170 generations. It appears that this artificial stimulation is in the line of the artificial fertilization of animal eggs which in recent years has attracted widespread attention. Dr. Calkins suggests that in nature constant environmental changes may stimulate the activities of Paramœcium, and that possibly conjugation occurs as a last resort when all other means of recuperation fail. These are some of the interesting results of these studies, which with a new series of animals are still in progress. (Archiv. für Entwickelungsmechanik der Organismen, Vol. 15, 139-186, 1902; and Biolog. Bull., Vol. 3, 192-205, 1902).

Chemotaxia in Fertilization of Animal Eggs. Recent studies of the fertilization of eggs of sea-urchin led to the conclusion that the meeting of the spermatozoon with the egg is a matter of chance, and not due to chemical attraction. This is in line with earlier observations on eggs of frogs and insects, and opposed to the general assumption of a chemotactic influence in the fertilization of animal eggs—an assumption based upon the well-known demonstrations that in certain plants chemical attraction is a factor in bringing sperm and egg into contact. (A. H. R. Buller in Quar. Jour. Mic. Sciences, Vol. 46, pp. 145-176, 1902).

Vital Units. Verworn's recent book on *Die Biogenhypothese* (Jena, 1903) is an important contribution to theories regarding the ultimate na-

ture of protoplasmic activity. He supports the view of biogenes as units of protoplasmic structure which are the centers of vital processes; and opposes the enzyme theory of the physiological chemists who regard life-activity as simply a chain of enzymic reactions. This is untenable because enzymic reactions, as now known, do not satisfactorily account for processes of constructive metabolism, although they might explain katabolism. Moreover, granting that vital processes are the expression of enzymic reactions, it seems necessary to postulate some unit of structure as the source of the enzymes, and this leads around to an equivalent of the biogene idea of a protoplasmic unit as the ultimate basis of vital activity.

Influence of Nutrition on Growth of Young Mammals. Recent studies by Dr. Margaret B. Wilson (Amer, Jour. Phy. Vol. 8, p. 192, 1902) show that new born pigs developed normally when fed with skimmed milk of cow, or with the same milk to which three per cent of dextrose or lactose has been added. Growth is proportional to the calorific value of the food—always supposing sufficient proteid to be present. This agrees with results of earlier students of growth in children and other young mammals. The pigs grew on the average about 215 grams for 1,000 calories in the food, and about eighteen per cent of the energy of the food was retained in the body as new tissue.

Sodium Chloride in Heart Activity. In line with Loeb's earlier work, Prof. Lingle of the University of Chicago concludes from a series of experiments that sodium chloride seems unique in having the power of renewing, or permitting the renewal, of rhythmic activity in narrow strips cut from the ventricle of the turtle's heart. (American Jour. Physiol., Vol. 8, pp. 75-98, Nov., 1902).

Unicellular Organisms and Stimuli. The ninth paper in the series of "Studies on Reactions to Stimuli in Unicellular Organisms," by Dr. Jennings, of the University of Michigan, deals with Stentor and Vorticella. In striking contrast with the author's earlier (1899) results on Paramœcium, concerning which it was concluded that its activities are machine-like and made up of few reflexes with little variation or adaptability, it appears from numerous experiments on Stentor that its behavior is very complex and adaptable. Indeed, there are all the outward indications of actions directed towards accomplishment of certain ends. On this ground some authors might attribute consciousness to these unicellular forms, as to higher animals. But Jennings insists that objective study can not settle the problem whether or not lower organisms have consciousness; the answer depends upon one's general system of philosophy. (Amer. Jour. Physiol., Vol. 8, pp. 23-60, Oct., 1902).

Metrology.*

METRIC SYSTEM EXERCISES.

BY E. C. WOODRUFF.

Instructor in Physics, La Grange, (Ill.), High School.

(Concluded from Page 30.)

Measurements of pressure.

(9) *To find the pressure of the school gas supply.*

(a) In a tube like (A) Fig. 1, with perpendicular sides and full of water to a given depth, obviously the water exerts a pressure on the bottom due to its own weight and equal to that weight.

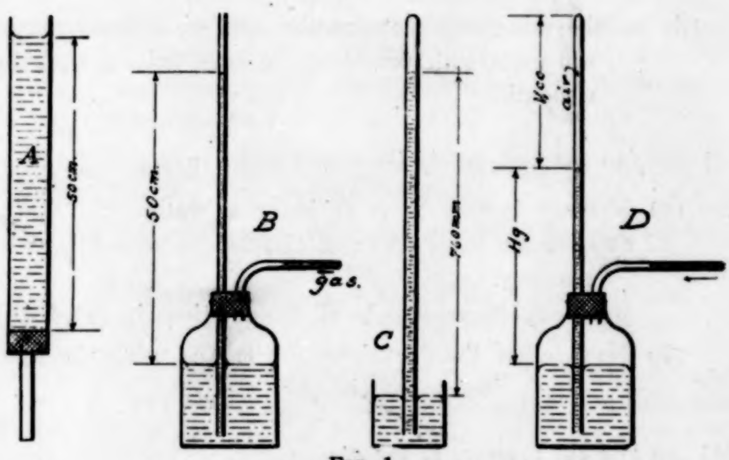

FIG. 1.

Suppose (A) has a diameter of 10 cm. and is full of water to a depth of 50 cm., what will be the pressure in grams on the bottom?

What will be the pressure in grams per cm.^{2}?

If the bottom is movable in the tube, *i. e.*, a piston, what force will be necessary to hold it in place? What force in grams for each cm.^{2} of its area?

* Communications for the Department of Metrology should be sent to Rufus P. Williams, North Cambridge, Mass.

What would be the answer to the last question if the diameter was 5 cm.? 1 cm.? How could you find the force in grams per cm. if you didn't know the diameter?

(b) Suppose (B) Fig. 1, called an "open manometer," is connected to the gas supply and the pressure of the gas forces the water to the height of 50 cm. as shown. What pressure would be necessary to support this height of water?

What, then, must be the pressure in grams per cm. of the gas supply?

(c) In this manner measure the actual gas pressure at frequent intervals for two weeks, recording the dates and hours.

(d) In the same way measure the maximum pressure you can exert with your lungs at least twice a week for a month.

(10) *To find the pressure of the school water supply.*

(a) Mercury is 13.6 times as heavy as water.

Suppose the tubes (A) and (B) in (9) were filled with mercury.

Work out the answers to all the questions in (a) & (b).

(b) Now follow the directions of (9) (c) using the water supply instead of the gas.

(11) *To find the pressure of the atmosphere.*

Read the barometer every day for a week.

(C) Fig. 1, shows the outline plan on which the barometer is constructed.

Now if the height of the mercury is 760 mm., what pressure in grams per cm. will be necessary to hold up such a column?

Record your observations thus:

(12) Suppose that to (D) Fig. 1, called a "closed manometer," sufficient pressure is applied so as to compress the V_1 cc. of air to ½ V_1 cc., then the pressure is twice what it was at first and we can form this proportion:

$$\frac{V_1}{\frac{1}{2}V_1} = \frac{\text{the new pressure}}{\text{the original pressure}} = \frac{2}{1}$$

But this same proportion will apply to any degree of compression, and so if V_1 becomes V_2 we have

$$\frac{V_1}{V_2} = \frac{\text{pressure to produce } V_2}{\text{pressure at first}}$$

Connect (D) to the water supply as follows:

(1) Measure the length of the air column $(= V_1)$
Measure the corresponding Hg. column $(= Hg_1)$

(2) Turn on the water and measure the new air column $(= V_2)$
And measure the new Hg column $(= Hg_2)$
Then we have

$$\frac{V_1}{V_2} = \frac{\text{pressure to produce } V_2}{\text{original pressure}}$$

$$= \frac{\text{Pressure of water supply + pressure of atmosphere — pressure of new Hg column}}{\text{`` `` `` — `` `` old `` ``}}$$

$$= \frac{P - Hg_2}{B - Hg_2} \left\{ \begin{array}{l} \text{where } B = \text{the reading of the barometer} \\ \text{and } P = \text{the pressure being measured} \end{array} \right.$$

Solving for P, $P = \frac{V_1}{V_2}(B - Hg_2) + Hg_2$

and P can be calculated because we know all the other quantities.

Calculate the pressure of the water supply thus and compare with (10).

Notes.

Teachers are requested to send in for publication items in regard to their work, how they have modified this and how they have found a better way of doing that. Such notes cannot but be of interest and value.

NOTES ON EXPERIMENTS.

The following notes on experiments are given to pupils in biological work, the second year in the high school to assist them in working out the conclusions for themselves. Is it not of fundamental importance that students should make their own inference and distinguish these from mere results observed? Are these suggestions too difficult for the comprehension of pupils of this grade? If this note does not draw out others on the subject of experiment writing, for pupils themselves, I shall be disappointed and shall have failed in my purpose.

"An experiment is for finding out something that it not naturally apparent or easily discovered. Experiments for discovering the way organisms do their work of living are physiological experiments.

In an experiment we alter the conditions in such a way as to find out the workings of nature. After the *altered conditions* (that were set up) have been left a sufficient length of time a *result* may be observed. From the result and the altered conditions a *conclusion* is drawn; *i. e.*, explaining the result. This may contain more than one conclusion—a simple and a more comprehensive one. These should be stated in the order of importance. The three steps in an experiment may be kept distinct and remembered more easily if the following facts are understood.

The altered *conditions* are *what we do* in setting up the experiment (only the essentials should be stated); the *result* is only *what we see* after the experiment has worked (not what we think or infer from what we see), the *conclusion* is what we *infer*, or *learn* from the experiment. It tells what we were trying to find out."

L. M.

BOTANY.

The Rise of the Transpiration Stream, an Historical and Original Discussion, is given by E. B. Oppeland in the September and October numbers of *The Botanical Gazette*. It presents and discusses several possible theories to account for the rise of the sap in the tree. Of these, according to the author, the most important is "the pressure of the

atmosphere against the water absorbed by the roots." Some play of surface tension is suggested as the missing link.

The author has not, however, confined himself to theories, having experimented long and carefully in the attempt to answer the question. But the important point is that, in spite of theories and investigation, the rise of sap in the tree is *not* yet explained. All the writer claims to have done is to have pointed out "where our theories fail and our deepest ignorance lies."

The President's address before the *Society of Plant Morphology and Physiology,* December 30, 1902, was given by Dr. V. M. Spalding, of the University of Michigan. In its course, he says: "We need to honor more than we do the man who knows how to see living things without complicated apparatus, and we need, cheerfully and without apology to ourselves, to give full days of active toil to learning and telling *what is.* It is far more difficult—after these years of laboratory supremacy—to teach a student to critically report in decent English a direct observation in the field than to secure from him a tabulated statement of artificially produced reactions.

The data for general conclusions are all too slow in coming in. This does not mean, however, that the scattering observations of every summer cruise, with half-baked notions of the "reasons of things," need be inflicted on the long-suffering readers of botanical literature. * * * * * The accumulation and expression of facts as they really are should take, as it seems to me, nine-tenths, possibly ninety-nine one-hundredths of the time that is being given to ecological work. Hypotheses are fascinating, but we have all erred, perhaps, in demanding that those who busy themselves with such observations shall show us promptly their bearing on a theory of the universe. * * * * * * Furthermore, a fact once established is just as good a fact and just as likely to have an important bearing if it is ascertained in a field or garden, in the depths of the Dismal Swamp or in the Sahara, as in a university laboratory."

In emphasizing the value of a plain, accurate statement of facts, Dr. Spalding mentions Paul Jaccard's study of plant distribution in Alpine regions, and speaks highly of Mohr's "Plant Life of Alabama." In conclusion, he adds: "Modern science, favored as never before, should be able to justify its cost to the state by contributing to the betterment of human life. Tested by its capacity to meet this demand, ecology, I think, will not be found wanting. Agriculture, horticulture, and forestry are practical applications of its principles. * * * * * I make no apology for thus emphasizing the practical value of this branch of scientific work. Service, first wrung from the unwilling slave, then the free-will offering of the citizen and patriot, is now the honorable goal of the worker in science, and there is no higher to be attained."

E. F. M.

PHYSICAL GEOGRAPHY.

Value of Aids to Study of Physical Geography.—I am always glad to know the views of my students concerning the plans and methods of our class work and sometimes I take special means to obtain them. I recently asked my class in physical geography to write in their order of help to each one the following aids which we had been using in our study of the land: Lantern slides, pictures, text-book and topographic maps. Of thirty-four answers received, the results are arranged in the following table, in which the figures express the nearest per cent:

	First.	Second.	Third.	Fourth.	First and Second.
Topographic Maps	47	38	9	6	85
Text-book	21	38	41	0	59
Lantern Slides	32	15	44	9	47
Pictures	0	9	6	85	9

Of course, the value of anything as spectacular as lantern slides is apt to be overrated, but the results are suggestive. If the first and second columns are added together, the order is, topographic maps, text-book, lantern slides and pictures.

GILBERT H. TRAFTON.

Book Reviews.

Nature Study and Life. By CLIFTON F. HODGE, Ph. D., Assistant Professor in Clark University. 13x19 cm., and ix + 514 pages. Ginn & Co., 1902. $1.25.

Too much in praise of this book cannot be said. Not only every teacher, but every parent should read it. The author's "point of view," which is developed in the first chapter, is briefly expressed in the formula, "Learning those things in nature that are best worth knowing, to the end ot doing those things that make life most worth living."

The values of nature study—economic, æsthetic, educational, ethical, religious—explained in chapter two in the author's own words, all aim at "character, will to do good, power to create happiness."

The greater portion of the book (twenty-five chapters) is devoted to practical suggestions as to the best things in nature to study and the methods of procedure to bring about the aim of education. And lastly is given a possible specific outline of work for the grades from the first to the ninth, inclusive.

Nature Study by Hodge is a success, because it not only sets forth the true ideals of education, but also suggests how to make these ideals practical.

BERNICE L. HAUG.

A Text-Book of Quantitative Chemical Analysis. By FRANK JULIAN. 16x24 cm., 604 pages. The Ramsey Publishing Company, St. Paul, Minn. 1902. $6.00.

Part I gives an outline of the general principles of the art of analysis and a description of the operations and appliances used. It is fully and well illustrated and right up to date.

Part II contains "a graded series of exercises, chosen with a view to illustrate the leading principles in analysis and afford practice in the usual manipulations." The choice is quite different from that of the usual run of books. Thus, the first third of the exercises has to do with the analysis of the following: Alcohol; lead carbonate; ferrous sulphate; sodium chloride; coffee; ginger; cast iron; ether; standard acid and alkali; vinegar and lemon juice. The directions are sufficiently explicit and are illustrated with specimen results.

In Part III the analytical behavior of a number of articles of commercial importance. The special methods and technical analysis cover a wide range of practice.

The most interesting feature of the book for the teacher of chemistry is perhaps the broad, philosophic view which pervades it. The author shows that he is indeed a chemist, and one with an extensive experience in analytical work. But he also shows that he is much more than that, for he has produced a book which treats of quantitative analysis, not as "a string of detailed recipes," but as a true branch of science; he has ever been at pains to emphasize the basic principles upon which the practice depends. The book teaches not only the art, but also the science of analysis. His "Notes on the Methods of Analysis" and Appendix on "Technical and Industrial Analyses" are replete with suggestions for the teacher, and the advice he gives "to the student, who proposes to adopt chemistry as a profession," is just what the teacher of chemistry should repeat to that boy who is so enthusiastically eager to become a chemist.

C. E. L.

Animal Forms; A Second Book of Zoölogy. By DAVID S. JORDAN, Ph. D., LL.D., President of Leland Stanford Junior University, and HAROLD HEATH, Ph. D., Professor in Leland Stanford Junior University. 13x20 cm., vi. and 258 pages. D. Appleton & Co. New York. 1902.

The number of biological textbooks written for elementary schools makes the selection of a name no small part of the task. It speaks well for the development of the subject in these schools, and if the good textbook were the principal requisite, certainly neither teacher nor pupil could complain of any want in this direction.

This is pre-eminently a reading book. At first we are at a loss to

know whether the title, *Animal Forms,* is to cover a more general treatise, not going so much into details of structure as might be expected in a zoölogy, or whether it is merely to give a new name to a new book.

After some preliminary remarks on the divisions of the subject of biology and the difference between animals and plants, the characteristics of higher animals—such as the pupil or a lay reader should know well—are given. The authors give, as an introduction, the structure of a higher animal, but this is done mostly in figures. It seems a little unfortunate that the animal chosen is a squirrel, which, while very interesting, is nevertheless one of those less familiar to the ordinary student. He is, therefore, not in so good a position to file away the information he obtains as he would be able to do in the case of a more familiar animal.

Very appropriately, this elementary general knowledge is then made use of in telling that the animal is really made up of an immense number of microscopic units—the cells. In the second chapter, under the "Cell and Protoplasm," typical animal tissue cells are discussed as to shape, size, and appearance. Naturally, the chapter on Protozoa comes next, and in this the somewhat usual types are discussed.

In the chapter on sponges, the gap between protozoa and metozoa is bridged by *pandorina* and *volvox,* bringing out here and at the end of the chapter the division of labor. Simple as the development seems to be rendered, it would better have been deferred till after the study of the anatomy. After the development there come, interestingly enough, "Distribution," a bit of ecology under "The Influence of Surroundings," then the Structure, Race and Life History.

The Coelenterata form the subject matter of Chapter V. In their description the story is freshly told and the student gets a good idea of these animals. The diagram illustrating the locomotion of a jelly-fish is very interesting.

In the next chapter, Worms—with their dorsi-ventral and bi-lateral symmetry—are introduced. The subject begins with the lower worms. While in the preceding types no systems of organs are referred to, here we have the digestive, excretory, and nervous systems. Form, habit, parasitism, life-history, regeneration, and spontaneous generation are all suitably given. While it might seem doubtful to introduce parasites thus early—before the anatomy of higher worms—no doubt interest is thereby stimulated, and so the subject helped.

Under "Animals of Uncertain Relationships" are placed Rotifers, Gephyrea, Sea Mats (Polyzoa), Brachiopods, Nemertian worms. Considering the relative unimportance of these, it would seem that somewhat too much space is given them in a crowded high school course.

Most of the animal types are discussed under "General Characters," "Internal Organization," "Others of the Same Group," "Development,"

but under Molluscs special senses are first brought in. After general characters in Arthropods, classification is introduced.

With equal fullness, and in similar fashion, the remaining groups of the animal kingdom are treated of in separate chapters, entitled Echinoderms, Chordates, Fishes, Amphibians, Reptiles, Birds, and Mammals. A little difference in arrangement would have left a clearer impression that *chordates* is a general term, including all the types that follow it.

The modern textbook, with its fine typography and its reproduction of photographic plates, is satisfying from the bookmaker's and the artist's standpoint, but hardly so from the student's. On a close application to its pages, the glossy surface becomes very trying to the eyes.

The language is sometimes not suited to the young student. It supposes him to know things that he does not know, things that the average student finds difficulty in apprehending. Throughout, the mere narrative or recital of facts is too crowded, and this is a drawback to the book. It is too condensed to keep up interest and is somewhat disconnected. It is too much of an epitome of the authors' wide knowledge.

L. MURBACH.

Reports of Meetings.

CENTRAL ASSOCIATION OF SCIENCE AND MATHEMATICS TEACHERS.

At the meeting in November of the "Central Association of Physics Teachers" (see this journal, Vol. II., p. 476), a communication was presented by a number of teachers of sciences other than physics, in which was urged the organization of the teachers of all sciences into an association similar to that of the physics teachers. This communication was favorably received and was referred to the executive committee. This committee, with the coöperation of a number of representative teachers in all the sciences, arranged for an organization meeting, held in Chicago at the Armour Institute of Technology on April 10-11, 1903. At this meeting, sections of biology, chemistry, earth science, mathematics and physics were formed in an organic relationship to one another. Great enthusiasm was manifested at the meeting, which, together with the numbers in attendance, showed that the association would be a success. A report of the general meetings is given below; the reports of the section meetings will follow later.

At 10 a. m. Friday morning, Mr. Charles H. Smith, president of the "Central Association of Physics Teachers," called the meeting to order and introduced Dr. Gunsaulus, president of the Armour Institute of

Technology, who welcomed most cordially those present as guests of the Institute. President Smith then stated the purposes of the meeting and made some appointments and announcements. Dr. A. P. Carman, Professor of Physics, University of Illinois, delivered an address on "Past and Present Theories of Electricity," which was followed by an address on "The Scientific Method in College and High School," by Dean S. A. Forbes, Professor of Zoölogy, University of Illinois.

After luncheon the laboratories and shops of the Institute were inspected, and at 2 p. m. meetings of the sections were held to perfect plans for organization and to listen to the programs prepared. At 6:30 p. m. a dinner was given at the Young Men's Christian Association building.

At 9:30 a. m. Saturday a constitution was adopted and the following officers elected: President, Charles H. Smith; secretary, C. E. Linebarger; treasurer, E. C. Woodruff. The appended resolution was unanimously adopted:

Resolved: 1. That it is the opinion of this association that the metric system of weights and measures should be used as far as feasible in all the science work of secondary schools.

2. That the advantages of the metric system, both in itself and as the system now in common use in the larger part of the civilized world are so great that its introduction into use in this country at the earliest practicable date is highly desirable.

3. The association strongly approves the immediate passage of a bill similar to H. R. Bill No. 123, 57th Congress, 1st Session.

4. In the belief that the international (metric) system of weights and measures will soon be adopted for this country also, the association recommends that this system be taught in all schools.

5. That a copy of these resolutions be sent to each senator and representative from the states represented at this meeting, and to the director of the National Bureau of Standards.

J. W. A. Young.
A. H. Sage.
J. J. Green.

THE PHYSICS CLUB OF NEW YORK.

The twenty-first regular meeting and second annual dinner of the Club was held at the Hotel Chelsae on Friday evening, February 6, thirty-five members being present. After the dinner, short addresses were made by Superintendent Bardwell on "Some Phases of Physics Study;" by Mr. A. L. Williston, of Pratt Institute, on "Physics and Engineering;" by Dr. Julius Sachs on "The Laboratory Method;" and by Principal W. B. Gunnison on "The Point of View of a High School Principal." An elaborate and very carefully prepared paper was then read by Mr. J. R.

Bibbins, of the Westinghouse Company, on "Recent Development and Use of Electric Power."

The twenty-second regular meeting was held at Columbia University on Saturday, March 21. For the apparatus committee, Mr. Bryant, of Erasmus Hall High School, explained two simple pieces; the first was designed to show the relative conductivity of iron and copper, and consisted of a combination of four binding posts, so arranged on a short board that between two of them a piece of iron wire could be placed, and between the other two a piece of copper wire of the same size. When arranged in series, the iron wire was quickly brought to a red heat, but when arranged in parallel the copper was as quickly heated and apparently to the same degree. The second piece of apparatus was designed for individual work in determining the latent heat of vaporization. It consisted of a spherical glass bulb, about two inches in diameter, with a flange on top, around which a stiff wire was wound and which supported the bulb over the Bunsen burner. The bulb was half filled with water, the temperature of which was taken. The time was noted when the flame was put under the burner, then again when the water boiled, and again when it was all boiled away. From these figures the latent heat was calculated. It was voted to continue the method of the current events committee and to print a list of articles found in current magazines as they appear, relating to matter in which the members are interested.

Mr. C. L. Harrington then read a carefully prepared paper upon "Becquerel Rays," stating how these were discovered, the history of their investigation and the present theory about them. He showed some prints made by some of his pupils from plates which had been exposed to these rays. Professor Pegram, of Columbia University, then performed some experiments, illustrating his investigations in the Bequerel and ultra-violet rays.

Prof. Ernest Merritt, of Cornell University, gave a clear and detailed description of the electron theory, explaining the deductions from the theory, one of which was that in certain phases of the subject the theory was in opposition to the theory of gravitation.

After lunch the members gathered in the Engineering building and listened to an address by Prof. M. I. Pupin on "Electrical Waves in Long Conductors." After the lecture the members were invited to visit Professor Pupin's laboratory and inspect the condensers which he has discovered for increasing the efficiency of long conductors.

Reported by R. H. Cornish.

A SHORT REPORT OF THE JOINT SESSION OF THE BIOLOGICAL SECTION OF THE MICHIGAN SCHOOLMASTERS' CLUB WITH THE SCIENCE TEACHING SECTION OF THE MICHIGAN ACADEMY OF SCIENCE.

The meeting opened with a report on "The Status of Physiographic Teaching in Michigan High Schools," by Prof. M. S. W. Jefferson, of the Ypsilanti Normal College. The report was based on circulars sent out to 108 schools; of these twenty-seven have geology, six doing laboratory work and seven taking field excursions. The majority have ten to twenty students in the classes. Lack of time and lack of material were given as the chief difficulties teachers had. Not many of the teachers had any special training, and the reported lack of material was thought to be due to the inability of teachers to understand what material was available.

"The Status of Biological Teaching" in the state was discussed from statistics by Miss Jessie Phelps of the Ypsilanti Normal College. Sixty-two per cent of the schools reported meet the requirements of the State University (one year of biology may be offered as a unit toward the fifteen required for entrance; this may be one year of botany, one year of zoölogy, or one-half year of each.) One-half year of each was given as the optimum, in the speaker's estimate. In one school two years of biological study are given, while in three none is given. Forty-three per cent give biology in the first year, forty-seven per cent in the second year and the rest scattering. In sixty-one botany is required, in twenty-five elective, and in thirteen scattering.

Prof. W. J. Beal of the State Agricultural College under the caption "Helps for High School Teachers of Natural Science," took rather a pessimistic view of the practical application of high school botany—at least, in his line. No way was suggested of bettering the teaching. New books, apparatus and teachers' classes were suggested as useful topics for teachers' meetings.

Prof. V. M. Spalding of the University of Michigan gave a very interesting and helpful talk on "What May Be Regarded as Settled in High School Biological Work by the Discussion and Practice of the Last Quarter Century." The principal thing is the well trained teacher; next to this laboratory work is absolutely essential. A special discipline is derived from the study of biology under proper teaching not derived from history, mathematics, Latin, etc. In addition to morphology and physiology of plants ecology should be given place; that is "a speaking acquaintance with plants." It was suggested this might be done at times when the pupil is not otherwise employed. The time to be spent is indicated in the requirement for entrance to the University: "What a Trained Teacher in

One Year Can Do in the Laboratory and Field." *Teaching cannot be defined or limited, as it is a perpetual experience."**

In a five minutes' talk on the "Greatest Needs of High School Biology," Dr. H. L. Clark of Olivet College, urged the natural history method of studying biology as the best. Much of his pleasure on excursions was derived from the early training he had had along this line—meeting old friends and making new ones among plants and animals.

Miss Mary A. Goddard of the Ypsilanti Normal College discussed "The Greatest Needs as Felt by the Schools Themselves." In the course of her remarks she emphasized the lack of preparation in the teachers and the fact that the teacher often has more other subjects to teach than biology, this being merely an adjunct. The remedies suggested were—better trained teachers, simple apparatus, library facilities and abundant material.

A spirited talk was given by Hon. Delos Fall, State Superintendent of Education on "The Consolidation of Rural Schools and the Rural High School." For these he advocated nature work and manual training; also domestic science. Teachers for rural schools would better be trained in these high schools by special teachers for this purpose, but ultimately they would better be trained in the Agricultural College than in the Normal Schools.

"The Value of Zoölogy in the High School," discussed by Mr. J. W. Matthews, of Detroit, was, in effect, that it can reach pupils better than any other study. It should be taught by laboratory and field work. Collecting specimens, and thus to some extent systematic work, may be done by children instead of "stamp or button collecting." He held that zoölogy should replace the teaching of physiology in the high school, as this was a time in the pupil's life when his attention was to be directed away from himself.

Prof. W. H. Sherzer of the Normal College, Ypsilanti, had sent out circulars to one hundred and ten high schools "Concerning the Collecting, Identification and Exchange of Natural History Material," and half of the schools expressed a willingness to exchange nearly every conceivable thing. He suggested that there should be a bureau established for facilitating such exchanges among the schools. A list of names was then given, of men in connection with various institutions in the state who would identify specimens that might be sent them, by teachers in the state. The list may be obtained from the writer, or from Professor Sherzer.

Miss Mary A. Goddard of the Normal College, discussed "The Course in Botany Proposed by the Society for Plant Morphology and Physiology." It was generally conceded that too much was attempted. She thought two years of botany would be too much. She would favor animal as well as plant ecology. The text book should always *follow* the laboratory work.

*The italics are the writer's.

On "The Best Books in Zoölogy for Laboratory, Recitation and Library," Dr. S. J. Holmes of the University of Michigan, spoke briefly and to the point. He advocated such books as give a well balanced course and bring in a reasonable amount of ecology. While it was well to introduce many questions, this may be overdone. In many books there are pointless questions, and some to which there can be no definite answer that would better be left out.

Prof. F. C. Newcombe of the University of Michigan, under the head of "The Best Books for Class Work in Botany," gave a list of the most available, and discussed the books from the standpoint of merit on the basis of all around work and accuracy. The number was finally narrowed down to two.

At the close of the meeting Prof. V. M. Spalding of the University, held a round table discussion for teachers especially interested. The principal trend of the discussion was that for higher general botanical work it is desirable that students should know not only the names of plants, but also much about the habits and habitats of trees and other common plants. It would not be difficult for the teacher to get this information, but in order to do good field work the teacher must have gone over the ground before the class is taken out to be perfectly familiar with the ground to be covered. It was held that field work was in general more onerous than laboratory work and this was in the way of its being done by many teachers who should do such work. It was also suggested that it was not so well understood, that teachers were not trained along this line, and naturally would not take it up.

Reported by L. Murbach.

EASTERN ASSOCIATION OF PHYSICS TEACHERS.

The thirty-fifth meeting of the Association took place in Worcester Saturday, February 21, 1903. The morning session was at South High School and the afternoon session at Clark University. The members were the guests of Mr. Calvin H. Andrews, teacher of physics in the South High School.

After the transaction of routine business, Mr. Andrews exhibited two new Atwood's machines and a device to illustrate the effect of parallel forces.

A letter was read from President Charles W. Eliot, of Harvard College, thanking the Association for its offer made at the preceding meeting to assist in any way possible to make the coming meeting of the National Educational Association in Boston a success. President Eliot suggested several ways in which the Association could render efficient service.

The address of the morning was delivered by Prof. F. S. Luther, of Trinity College, Hartford, Conn. The subject of the address was the "Study of Mechanism." Before Professor Luther had finished, some of his hearers were surprised, for he made a strong and forceful plea for a readoption of some of the methods formerly employed in teaching physics. Greater attention to mechanics was one of them.

In beginning, he said he did not want anything he might say to be construed as having any bearing on the question of qualifications for entrance to college. He also wanted to say he is not an old fogy. He believed as fully as anyone in adopting new and modern methods. He felt it necessary to make this statement in the beginning, for he had some fear it might not be accepted at the conclusion of his remarks. While he favored new methods and apparatus, he also desired to make a plea for some of the old things. It was this idea which caused him considerable difficulty in selecting a title for his address. He at first intended to call it "A Forgotten Branch of Physics," but rejected this title, because it might prove misleading.

The importance formerly attached to mechanics as a branch of physics has, to a great extent, declined in the last few years, owing to the wonderful advancement made in other directions. After recounting some of the most important discoveries, he said that, notwithstanding them, he still doubted the wisdom of removing the emphasis from the study of mechanics or "what makes the wheels go round." "What has become of the old machines?" he asked. "Do they still figure in your work? What has become of the lever, the wheel and axle, the inclined plane, the pulley and the combination of pulleys? In many instances they have disappeared from the physical laboratory. The boy who has studied physics, on seeing a derrick working in the street, will probably understand the relation between power and speed, but I believe the boy would understand it better had he studied under the old system."

One grave question which enters into the matter is, what mathematics is needed to study physics? In his opinion, the student should understand the elements of algebra and graphic geometry, and also be able to apply the principles of the parallelogram of forces. He did not consider it necessary for a boy studying elementary physics to understand trigonometry. A boy can solve any problem involving the parallelogram of forces with a lead pencil, a straight edge, a 60-30 triangle and a protractor. The simple roof truss, with the weight concentrated at the joints, can be solved without the assistance of higher mathematics, and is so solved every day by practical builders.

"I do not believe," he said, "in teaching pupils to solve problems by old methods when they can solve them so much easier by modern methods. In my opinion, no living mortal ever has understood the binominal theorem until he has reached calculus. A boy or girl should not be allowed to use a formula he cannot understand. A great deal more time

should be devoted to the laws of falling bodies than there is at present. It does not make any difference whether the pupil is going to college or not, he should be made to do more problems of this kind."

In referring to one of the modern machines for illustrating the laws of falling bodies, explained a few minutes before by Mr. Andrews, he said he recalled a contrivance for the same purpose, which consisted merely of channels lined with vellum cut in a plank. Marbles were allowed to roll down the channels, and, with an arrangement of this kind, Galileo succeeded in demonstrating in a satisfactory manner the laws of falling bodies. A member of the Association asked if Galileo's presence would be necessary to secure the same results. The speaker calmly replied he understood Galileo is dead, but he would undertake to adopt his method and would secure fully as satisfactory results as any member of the Association could with any of the modern machines.

Professor Luther laid special stress on the necessity of giving boys an abundance of problems dealing with the laws of falling bodies. He said: "It is a good thing to adopt this method at the beginning of the study of science. The human boy requires training of this kind from infancy until he has reached his sophomore year in college, when he knows all things."

Continuing, he said: "The study of mechanism appeals directly to a pupil's senses as molecular physics does not. The operation of a train of mechanism can be seen and followed step by step. Molecular physics requires a great deal of trained imagination, which the average grammar or high school pupil does not possess. A boy knows what it means to lift a pound or to move an object ten feet. He knows what an object looks like when it is moving at the rate of a mile in three minutes. Mechanics appeals to him, for he is familiar with such things. It is entirely different with molecular physics, and it does not appeal to him."

The speaker said he believes in the metric system and favors its universal adoption, but until it is universally adopted, better results can be obtained in teaching mechanics by allowing the pupil to use foot pounds instead of any of the standards of the C. G. S. system. He did not consider it advisable at present to use the metric system in teaching mechanics in grammar and high schools.

Professor Luther heartily indorsed the laboratory method of teaching physics, but plainly said he did not believe in complicated machines. Simple machines were superior to all others in demonstrating the principles of mechanics. He said: "In the interest of simplicity, let machines be simple and inexpensive. The purpose of the laboratory apparatus is not to obtain exact results, but to teach the pupil the principle of the law under consideration. Exact results cannot be obtained even with the most costly and complicated appliances. The study of mechanics conduces as nothing else does, the realization of the necessity for accuracy in mathematics. The lack of realization of the necessity for obtaining the exact answer every

time has cost builders and contractors many thousands of dollars. It is hard to impress on the mind of the young engineer the necessity of figuring absolutely correct. I am almost ashamed to tell of a mistake of one of my former pupils. He made the plans for conveying oil through a pipe from a large tank to a station some distance away. It was planned to have the oil flow into the station by gravity, but when his plans had been followed and the work completed, it was found the pipe entered the station five feet higher than the source of supply. The student of mathematics comes continually in contact with absolute truth as in no other branch of work. It is the truth, the same today as yesterday, and as it always will be. This is not so in other lines. History may not always be the truth, but lies officially agreed upon. It is not true of physics, for I learned things thirty years ago which I now know are not so, and even in chemistry I learned the other day my old friend, the atomic theory, is in bad shape, very bad shape. Mechanics can teach students that accuracy in mathematics is necessary, not to satisfy a fad of his tutor, but as one of the requirements of success in practical life."

In closing, Professor Luther said: "I do not plead for the accuracy which demands the uses of unnecessary decimals or decimals beyond a practically unobtainable point, but the accuracy required for all practical purposes, so that 2 and 2 shall always make 4, and never 5 or 3."

Mr. A. B. Kimball, of Springfield, presented a partial report from the committee appointed to investigate the subject of "Correlation of work in manual training and physics." Mr. Kimball said the committee received letters from teachers in all sections of the country that showed an effort in this line is being made generally, which will seem to show the necessity for correlation in these branches is realized, but no effective and satisfactory system has been evolved. It is the opinion of the committee that to secure satisfactory correlation in the teaching of manual training and physics it will be necessary for the teachers of physics to possess a practical knowledge of manual training, and, in this respect, graduates of technical schools should be preferred and the teachers of manual training should also have a knowledge of physics.

The following officers were elected for the ensuing year: President, F. M. Gilley, Chelsea; vice-president, G. A. Cowen, Boston; secretary, Clarence Boylston, Milton; treasurer, Irving O. Palmer, Newton; executive committee, N. H. Black, Roxbury, C. C. Hyde, Hartford, Conn., and John W. Hutchins, Malden.

Mr. A. B. Kimball, of Springfield, spoke in favor of a general organization, to be composed of associations of teachers of various branches of educational work. The suggestion was favorably received and Mr. Kimball and Mr. John C. Packard were appointed to investigate the matter.

After adjournment the members proceeded to the physical laboratory at Clark University, where they listened to a lecture on "The Measurement

of Sound and the Efficiency of Musical Instruments," by Prof. A. G. Webster.

After brief preliminary remarks concerning the peculiarities of hearing as manifested by various people, Professor Webster proceeded to explain the methods he had devised of correctly measuring the efficiency or sounds of all kinds. He first told of the units of measurement he used in determining the amount of energy employed in producing a sound of certain pitch and volume, and what percentage of the energy was effective. He described a piece of apparatus, of his own invention, which produces a continuous tone of fixed pitch. In connection with this invention, it may be said that its efficiency in producing sound from a given amount of power is greater than that of any other device known. It is easy to determine the amount of power used to produce the required tone, for it is merely necessary to measure the amount of electrical energy consumed.

Professor Webster told of the success that attended his efforts in measuring the efficiency of sound produced in various ways. One of his most interesting experiments was when Creatore's band was in Worcester, when several of the musicians were induced to visit Clark University to enable Professor Webster to determine the efficiency of their instruments and what percentage of the energy applied to produce tones was effective. Some idea of the difficulties encountered in carrying out these experiments may be derived from the fact that to make the experiments successful it was necessary to determine the volume of air the musicians took into their lungs and the pressure at which they blew into their instruments. These difficulties were overcome by Professor Webster, and he was able to discover the efficiency of the instruments, which in all cases was low compared with the energy employed to produce the sounds. Tests with the human voice showed its efficiency greater than that of any of the instruments experimented with, including the cornet, French horn, clarinet, oboe, saxophone and violin.

In closing his lecture, Professor Webster advised his hearers not to buy stock from any promoter who planned to collect the noises on the street and transform them into mechanical energy, for the amount of power thus obtained would be exceedingly small. Sousa's band makes a great noise in the hall, but the percentage of energy employed in making the noise which becomes effective is so small one might almost say Sousa is not so great after all. It would probably prove more costly to transform mechanical energy into sound than any other transformation of energy which might be suggested.

When asked if he had any commercial plans in view concerning his inventions, Professor Webster said he has not, up to the present time, and the only practical use he has thought of is that his invention for producing sound, being more efficient than any other, might save hundreds of tons of coal for the government if employed in place of the steam

fog signals now used along the coast, but he has no intention of devoting it to this purpose. He said it might also prove valuable in determining defects of hearing.

The visitors were permitted to see both machines in operation and to observe exactly how they work.

Reported by LYMAN C. NEWELL.

Correspondence.

AN EXPERIMENTAL ILLUSTRATION OF OSMOTIC PRESSURE.

EDITOR OF SCHOOL SCIENCE:

In the introduction to his note under the above title in the March number (Vol. II., p. 522) of this journal, Mr. C. F. Adams remarks upon the trouble teachers experience in illustrating osmosis by the methods usually given in the textbooks. There is, however, one simple and certain method, simpler and more certain than that Mr. Adams gives, namely, the use of Schleicher and Schüll diffusion shells, attached to tubes of appropriate size. These shells, which may be bought at about 25 cents each from the Bausch & Lomb Optical Co., of Rochester, or from Eimer & Amend of New York, come in two sizes, each 10 cm. long, and 16 and 40 mm. diameter, in form like the finger of a glove. If one of the 16 mm. size is soaked and tied tightly with waxed thread over the end of a tube of the same diameter, is filled with molasses (which has many advantages, of which its color is one) and placed in water, the liquid will rise 25-35 cm. in the tube within twenty-four hours and 50-60 cm. before it stops. If, instead of the large tube, a rubber stopper be used with one hole through which barometer or capillary tubing is thrust, the ascent of the liquid will be so rapid (even to 10 cm. a minute in tubing of 0.05 mm. bore) that the movement can be seen from a considerable distance. These shells can be kept always ready for immediate use and may be used again and again. Furthermore, they may very readily be made semi-permeable by soaking them over night in a 3 per cent solution of copper sulphate (preferably first exhausting the air from them under the solution by an air pump), and afterwards rinsing them out and filling them with a 5 per cent solution of potassium ferrocyanide which is to be left several hours. Thus treated they will send the liquid up tubes of 16 mm. outside diameter fully three meters, affording a remarkably striking illustration of osmotic pressure. They may also be attached to pressure-gauges, but I find that they burst themselves, when made semi-permeable, at a pres-

sure under two atmospheres. But upon this subject, especially in its relation to the phenomena of absorption of water by plants, I expect to write further in an early number of this journal.

There are two other reasons why I think these shells, especially if used with calibrated tubes, are superior to such devices as those described by Mr. Adams, excellent though the latter are. First, they show the process in much greater simplicity than the carrot, for we are dealing with a single membrane and not with a complicated structure, the operation of which needs considerable explanation. Second, and more important, the experiment with the shells can be conducted with a precision and neatness far more illustrative of the real nature of scientific work than is possible with the make-shift devices. I have myself been a great advocate of home-made apparatus and make-shift methods, even going so far as to maintain that upon the whole such self-made arrangements are educationally superior to those that could be purchased especially made for the purpose. But increasing experience is making me change that opinion, and chiefly for the reason that these make-shift devices introduce the students to a wrong ideal of scientific work, and one which it is almost impossible for them to get rid of afterwards. The very soul of scientific experiment is precision and simplicity, or I might say precision, which presupposes simplicity; and it is most desirable that students shall receive this impression of it at the start. Make-shift devices are better than none, but the precise arrangements are best.

Smith College. W. F. Ganong.

Answer to Question.

30. *Where can I find the addresses of dealers in live animals, such as turtles, birds, guinea pigs, rats, white mice, frogs, etc.?*

The following individuals or firms carry a more or less complete stock of the animals above specified:

A. A. Sphung, North Judson, Ind.
Brimley Bros., Raleigh, N. C.
Brooklyn Biological Supply Co., 333 Halsey street, Brooklyn, N. Y.
Ad. Kirchoff, 276 East Division street, Chicago, Ill.
W. H. Ficklin, 2640 E. 8th street, Kansas City, Mo.